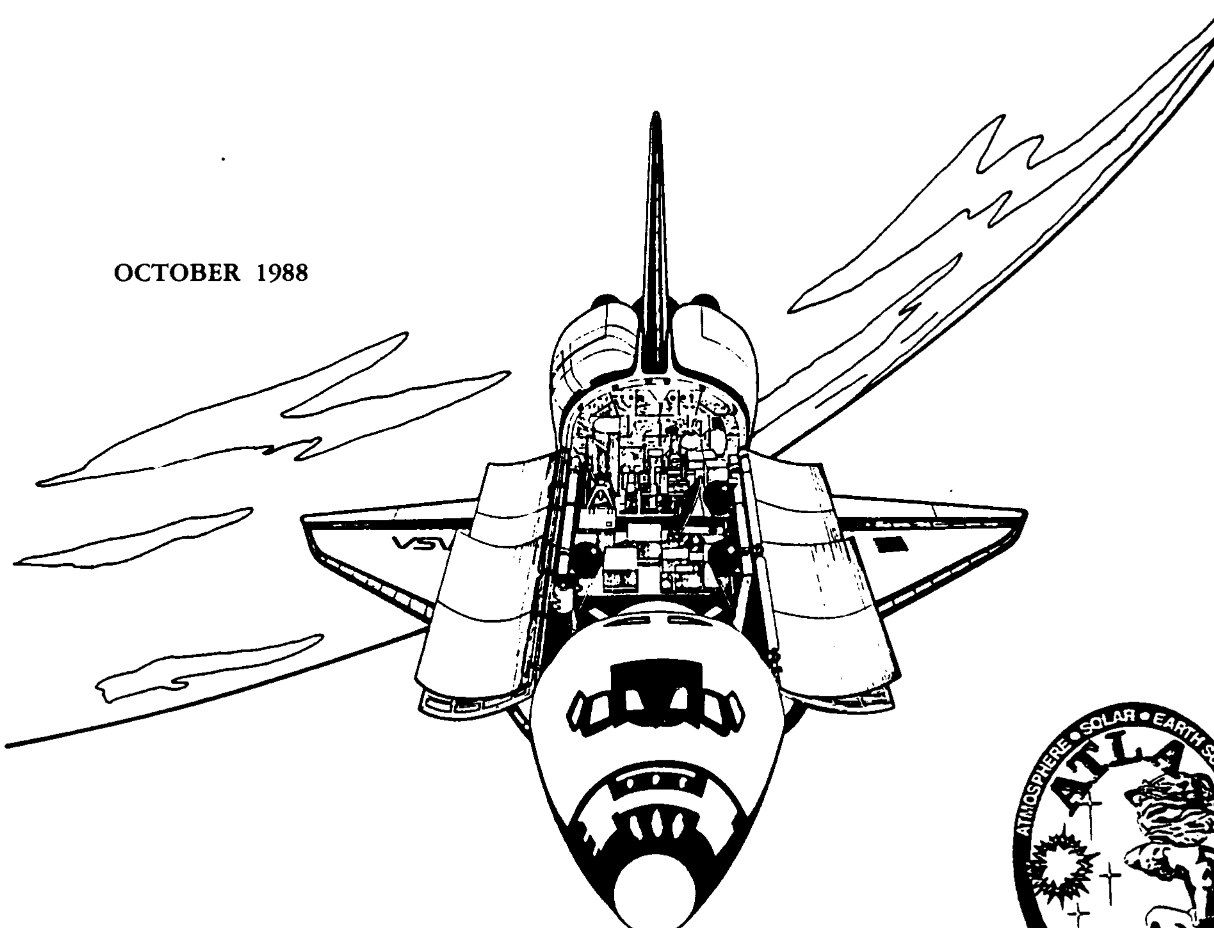
NASA Technical Memorandum 4101

Atmospheric Laboratory for Applications and Science Mission 1

OCTOBER 1988



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(NASA-TM-4101) ATMOSPHERIC LABORATORY FOR APPLICATIONS AND SCIENCE, MISSION 1 (NASA. Marshall Space Flight Center) 65 p CSCL 22A

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NASA TECHNICAL MEMORANDUM 4101

ATMOSPHERIC LABORATORY FOR APPLICATIONS AND SCIENCE MISSION 1

EDITED BY PAUL D. CRAVEN AND MARSHA R. TORR

OCTOBER 1988

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NASA Technical Memorandum 4101

Atmospheric Laboratory for Applications and Science Mission 1

Edited by
Paul D. Craven and Marsha R. Torr
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

National Aeronautics
and Space Administration

Scientific and Technical Information Division

1988

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TECHNICAL MEMORANDUM

ATMOSPHERIC LABORATORY FOR APPLICATIONS AND SCIENCE (ATLAS), MISSION 1

INTRODUCTION

The first Atmospheric Laboratory for Applications and Science (ATLAS 1) is a NASA mission with an international payload, with the European Space Agency providing operational support for the European investigations. The ATLAS 1 represents the first of a series of shuttle-borne payloads which are intended to study the composition of the middle atmosphere and its possible variations due to solar changes over the course of an 11-year solar cycle. One of the ATLAS missions will coincide with NASA's Upper Atmospheric Research Satellite (UARS) mission and will provide crucial parameters not measured by the instrument complement on the satellite. A first in this evolutionary program, the ATLAS 1 will carry a payload of instruments originally flown on the Spacelab 1 and Spacelab 3 missions. The Atmospheric Laboratory for Applications and Science Mission therefore exploits the shuttle capability to return sophisticated instruments to the ground for refurbishment and updating, and the multi-mission reflight of the instruments at intervals required by the scientific goals. In addition to the investigations specific to the ATLAS objectives, the first mission payload includes others that are intended to study or use the near Earth environment.

The primary components of the equipment for Earth investigation are mounted on two pallets as shown in Figure 1.

Overall management of the ATLAS 1 is assigned to the Office of Space Science and Applications at NASA Headquarters. The Marshall Space Flight Center (MSFC) in Huntsville, Alabama, is the project management center for the mission. Dr. D. Butler of NASA Headquarters has been designated the Program Scientist for ATLAS 1 and Dr. M. R. Torr of MSFC is the ATLAS 1 Mission Scientist. ATLAS 1 investigations originate from the United States, Japan, Belgium, France, and Germany. Figure 2 shows the geographic distribution of the Principal Investigators for ATLAS 1.

The first ATLAS will be launched from the Kennedy Space Center (KSC). The mission duration is planned for 9 days at an orbital altitude of 250 km and an inclination of 57 degrees. Launch is presently planned for late 1990.

A total of seven crew members will operate the science instruments, the Spacelab systems, and the Orbiter. The Orbiter will be operated by the Commander and Pilot. Mission Specialists will be primarily responsible for the operation of the Spacelab systems, but will also be involved in the conduct of scientific investigations. The Payload Specialists, Drs. B. Lichtenberg and M. Lampton, are scientist crew members selected by the scientists who have developed the investigations for the mission.

Science operations will be conducted continuously during the mission, requiring alternate 12-hour shifts by the onboard crew and around the clock support by the mission planners, controllers, and science teams. A cadre of support personnel will direct and assist the onboard crew in performing the investigations according to a preplanned timeline, which can be revised throughout the mission if circumstances

require it. Science operations will be directed, with guidance from the investigators, by the Mission Scientist.

At present, the mission science payload comprises 11 investigations. These are located on the pallets. Several of the instruments have dedicated experiment controllers located in the aft flight deck (AFD) for access by the flight crew. The physical location of each instrument is shown in Figures 3 and 4.

The first ATLAS is a multi-discipline mission, comprising four broad areas of science: Atmospheric Science, Solar Physics, Space Plasma Physics, and Astronomy. Table 1 lists the investigations by number, discipline, title, principal investigator, and the sponsoring country or organization.

The atmospheric science investigations will study the composition of the atmosphere in the stratosphere, mesosphere, and thermosphere (15 km to >250 km). These observations will employ a variety of spectrometric techniques extending from the extreme ultraviolet to the millimeter wavelengths, using both the emission and absorption of light by the atmosphere.

The solar physics investigations will measure the total energy output of the Sun using three different methods. The goal of these investigations is to determine quantitatively and with precision any variations in the solar energy output. Such information is important not only for its effect on the composition of the Earth's atmosphere and ionosphere, but also to studies of physical processes on the Sun and for studies of the Earth's climate.

Space plasma physics investigations will study the charged particle and plasma environment of the Earth. Both active and passive probing techniques will be used to investigate key cause-and-effect relationships that couple the Earth's magnetosphere, ionosphere, and atmosphere. Electron and plasma beams will be injected into the ambient plasma in order to study phenomena such as aurora and spacecraft charging.

The astronomy investigation will study astronomical sources of radiation in the ultraviolet wavelengths that are inaccessible to observers on Earth.

The investigations that comprise the ATLAS 1 mission will acquire fundamentally important knowledge of the physical processes which control man's environment.

The experiment descriptions in this report have been grouped into four sections, each corresponding to one of the discipline groups.

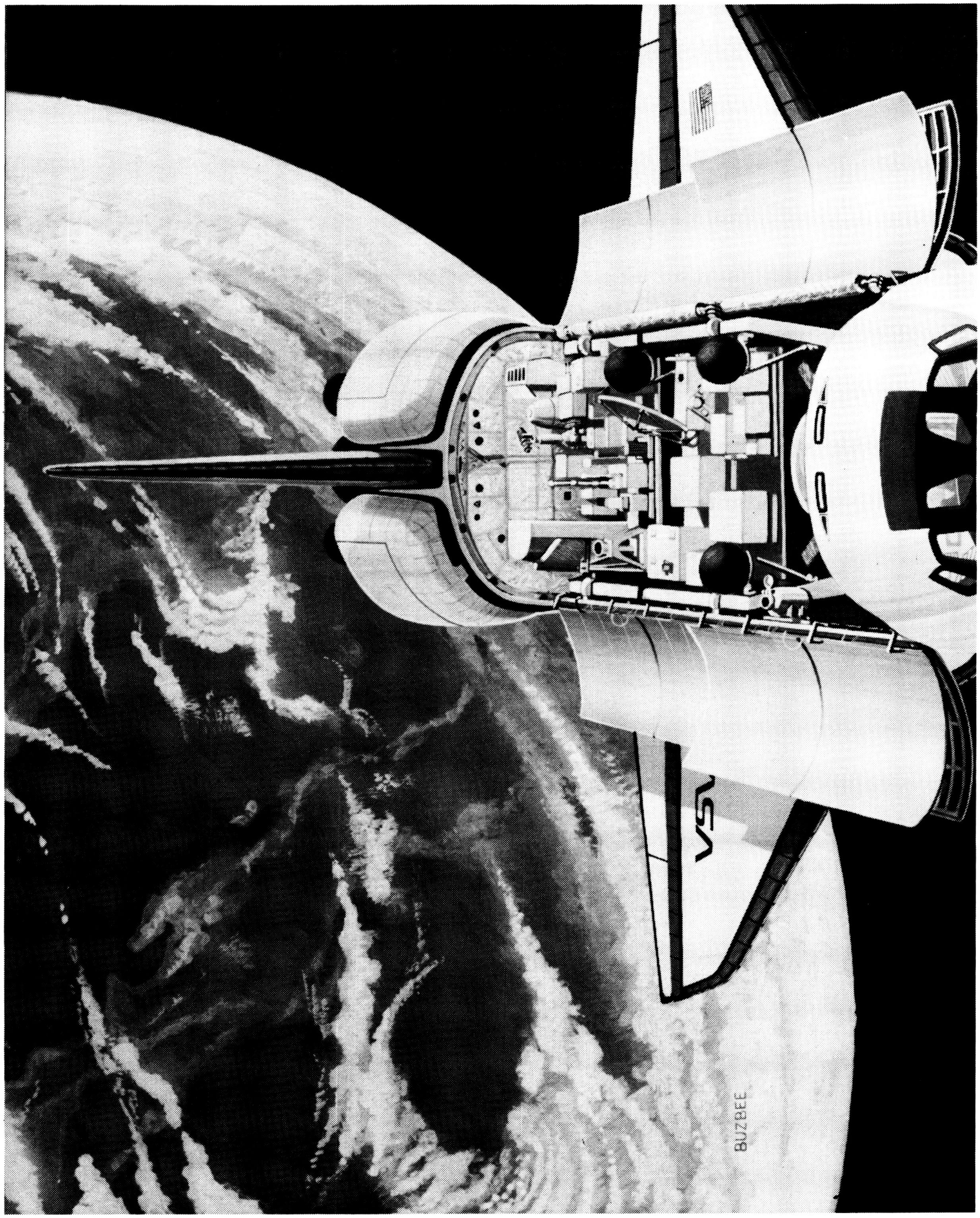

Figure 1. ATLAS 1 mission configuration.

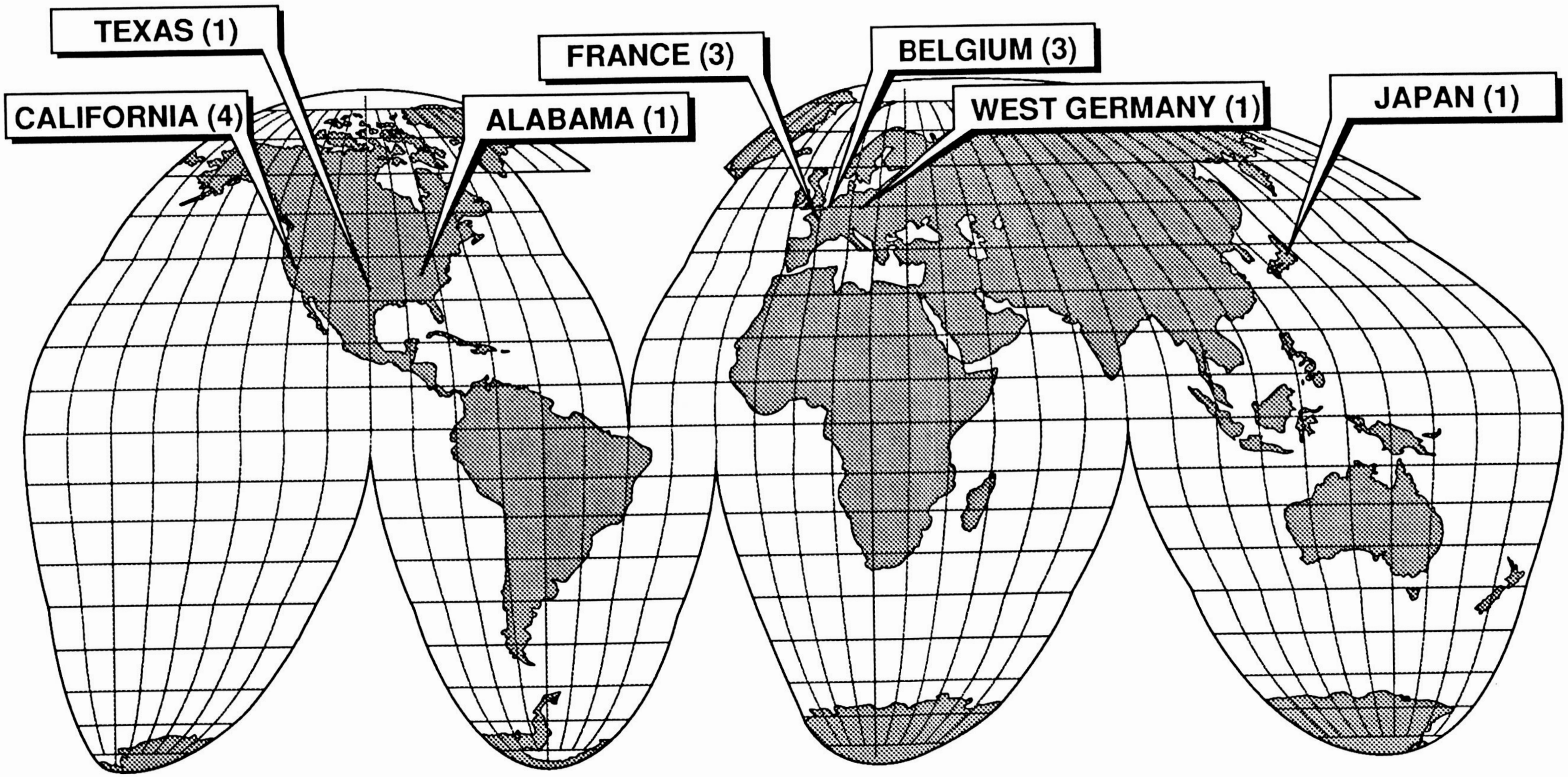

Figure 2. Geographic distribution of the investigators for ATLAS 1.

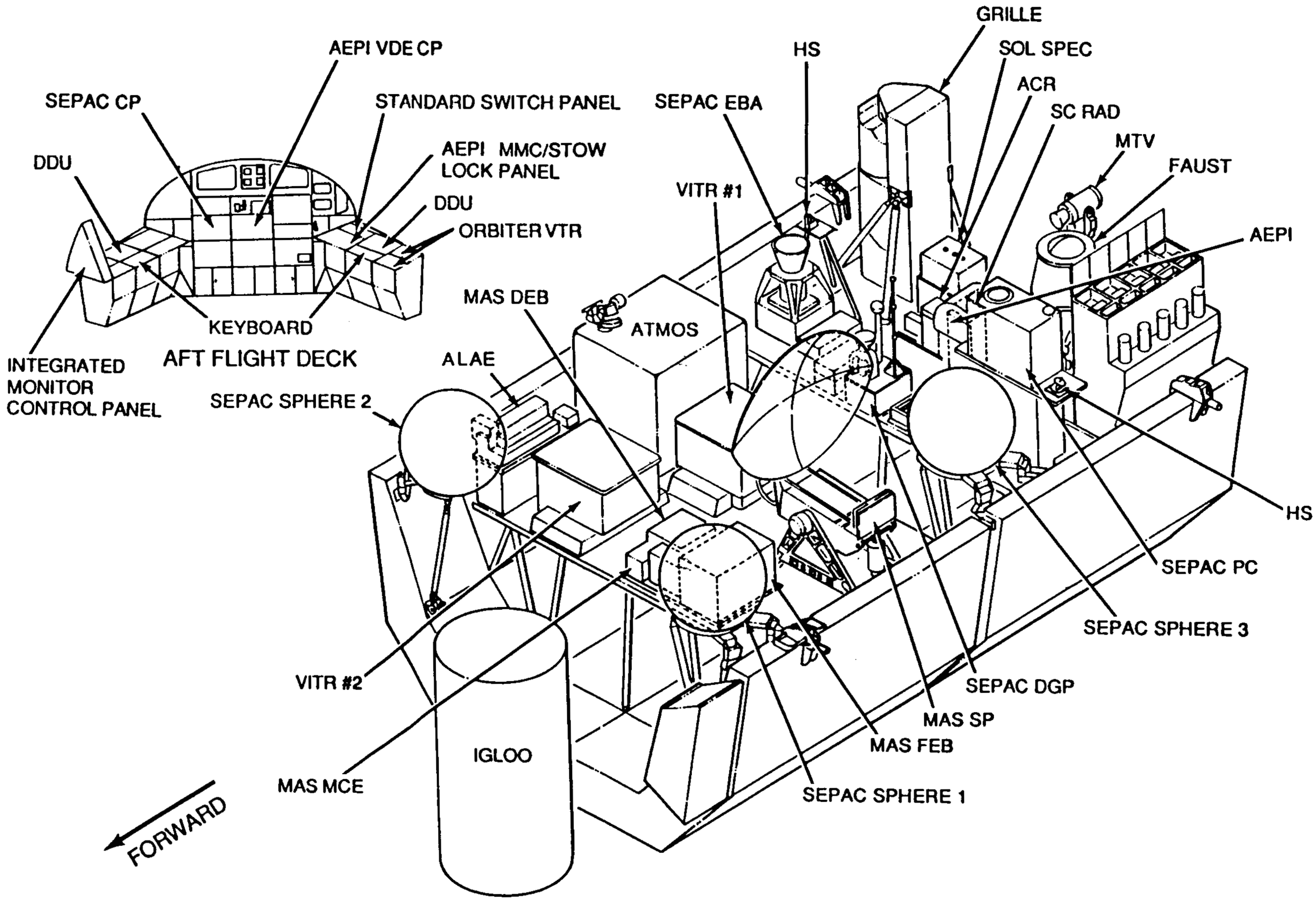

Figure 3. ATLAS 1 pallet plan view.
(NOTE: The position of the instruments in the final flight configuration may differ slightly from that shown here.)

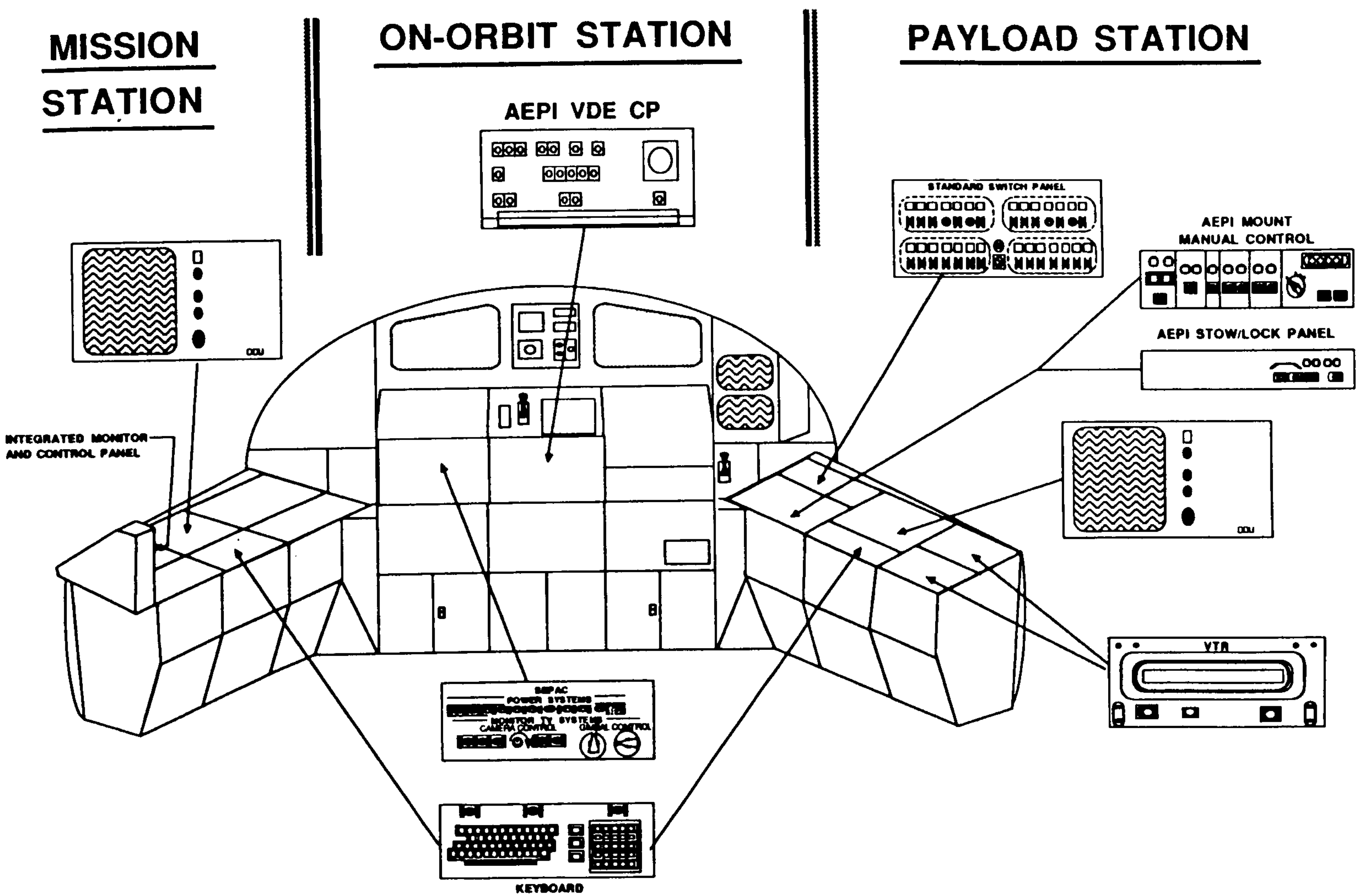

Figure 4. Layout of aft flight deck on ATLAS 1.

TABLE 1. INVESTIGATION TITLES AND PRINCIPAL INVESTIGATORS

Discipline	Experiment Number	Title	Principal Investigator/ Sponsor
Atmospheric Science	E017	Atmospheric Lyman-Alpha (ALAE)	J. L. Bertaux/France
	N009	Atmospheric Trace Molecule Observed by Spectroscopy (ATMOS)	C. B. Farmer/NASA
	E013	Grille Spectrometer (Grille)	M. Ackerman/Belgium J. Besson/France
	N001	Imaging Spectrometric Observatory (ISO)	M. R. Torr/NASA
		Energetic Neutral Atom Precipitation (ENAP)	B. A. Tinsley/NASA
	E034	Millimeter-Wave Atmospheric Sounder (MAS)	G. K. Hartmann/ W. Germany
Solar Physics	N008	Active Cavity Radiometer (ACR)	R. C. Willson/NASA
	E021	Solar Constant (SOLCON)	D. Crommelynck/ Belgium
	E016	Solar Spectrum (SOLSPEC)	G. Thuillier/France P. Simon/Belgium
Space Plasma Physics	N003	Atmospheric Emissions Photometric Imaging (AEPI) Experiment	S. Mende/NASA
	N002	Space Experiments with Particle Accelerators (SEPAC)	T. Obayashi/Japan
Astronomy	N005	Far Ultraviolet Astronomy Space Telescope (FAUST)	C. S. Bowyer/NASA

SECTION I

ATMOSPHERIC SCIENCE

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ATMOSPHERIC LYMAN-ALPHA EMISSIONS (ALAE)
(E017)

J. L. Bertaux
Service d'Aeronomie du CNRS, France

The Atmospheric Lyman-Alpha Emissions (ALAE) experiment is designed to measure atomic hydrogen and deuterium in the terrestrial atmosphere. The development of the instrument is a joint effort of the Service d'Aeronomie du CNRS in France and the Institut d'Aeronomie Spatiale in Belgium.

The detecting technique is based on the capability of atomic hydrogen and deuterium to absorb the intense solar Lyman-α radiation at 121.6 nm and to re-emit this radiation in a different direction. Since the wavelengths of the deuterium and hydrogen Lyman-α lines are very close, specific absorption cells (Fig. I-1) are used to discriminate between the atmospheric deuterium and hydrogen emissions. Light entering the instrument falls on a rotating mirror used for pointing toward different atmospheric regions. When the hydrogen cell is activated, almost all Lyman-α emission from atomic hydrogen is absorbed and the grating eliminates all other atmospheric emissions from other constituents. By switching the deuterium cell successively on and off, the photomultiplier can detect the weak atmospheric deuterium emission. Various combinations of the status of both cells during the mission allow observations of the atmospheric deuterium layer, the atomic hydrogen geocorona, and the Lyman-α interplanetary medium. The mass of the instrument (Fig. I-2) is 12.5 kg and its dimensions are 685 x 300 x 320 mm.

Atomic hydrogen in the Earth's atmosphere results essentially from the evaporation of liquid water at ground level followed by an upward transport of water vapor to altitudes where it is dissociated by solar ultraviolet radiation. Atomic hydrogen then becomes an atmospheric component involved in numerous chemical reactions and is capable of escaping the Earth's gravitational field. Since liquid water also contains a small fraction of molecules in which one hydrogen atom is replaced by one deuterium atom, which is twice as heavy, it is reasonable to suspect the presence of a small amount of deuterium in the upper atmosphere.

In 1983, the ALAE experiment (ES017) discovered three new features during the Spacelab 1 mission. For the first time, an atomic deuterium layer was detected around 110 km altitude (Fig. I-3) with an intensity of 330 Rayleighs (1 Rayleigh = 10^6 photons cm^{-2} s^{-1}). Auroral emissions of atomic hydrogen were monitored on the dayside as well as on the nightside. A hot, unexplained emission outside of the auroral region was observed during the last day of the mission. These results indicate the flexibility of the instrument and its potential capability to investigate a wide range of geophysical phenomena. The technique could be adapted to other planetary missions in order to evaluate the ratio between deuterium and hydrogen which is a fundamental quantity necessary for the understanding of the time evolution of water on a planet.

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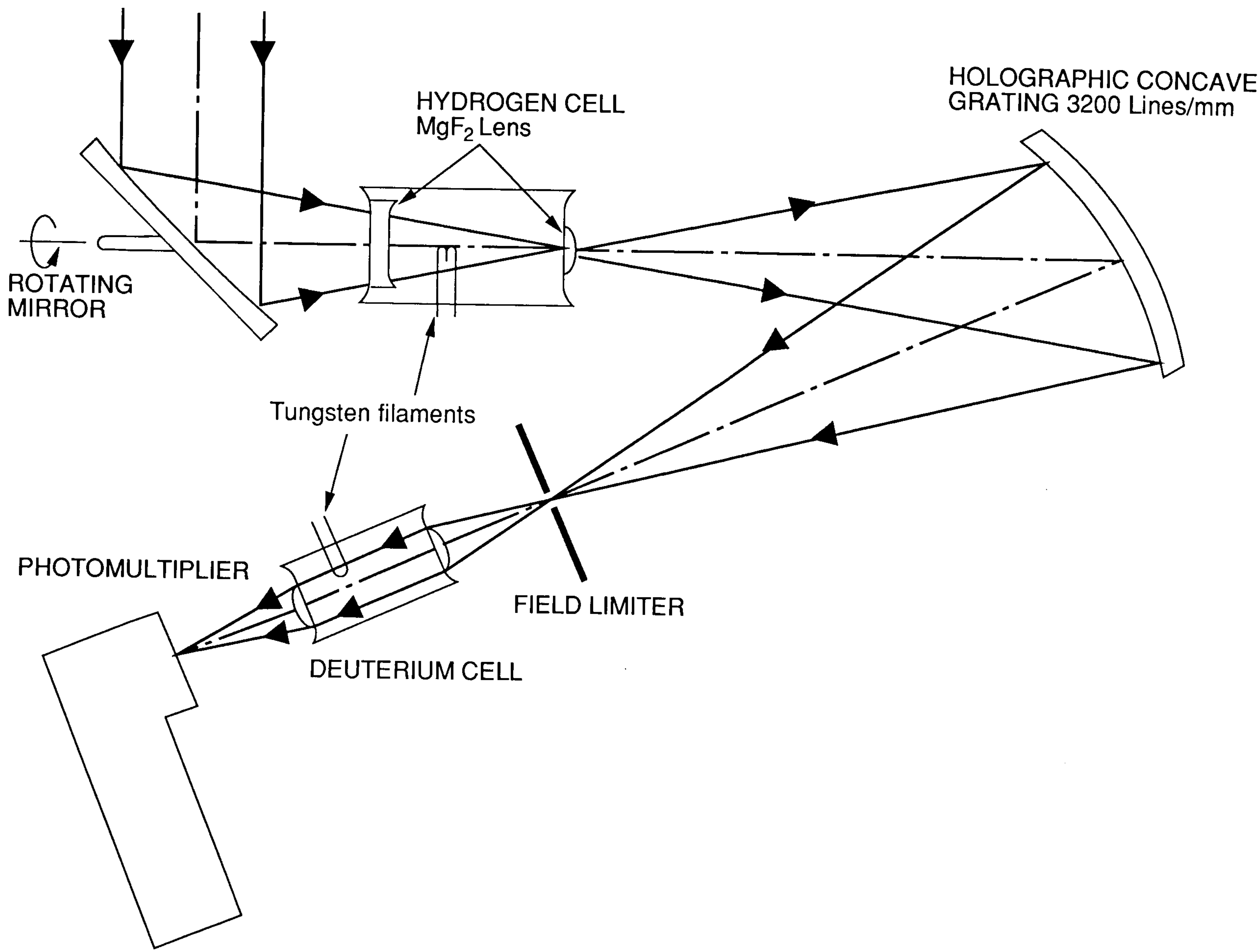

Figure I-1. ALAE instrument schematic.

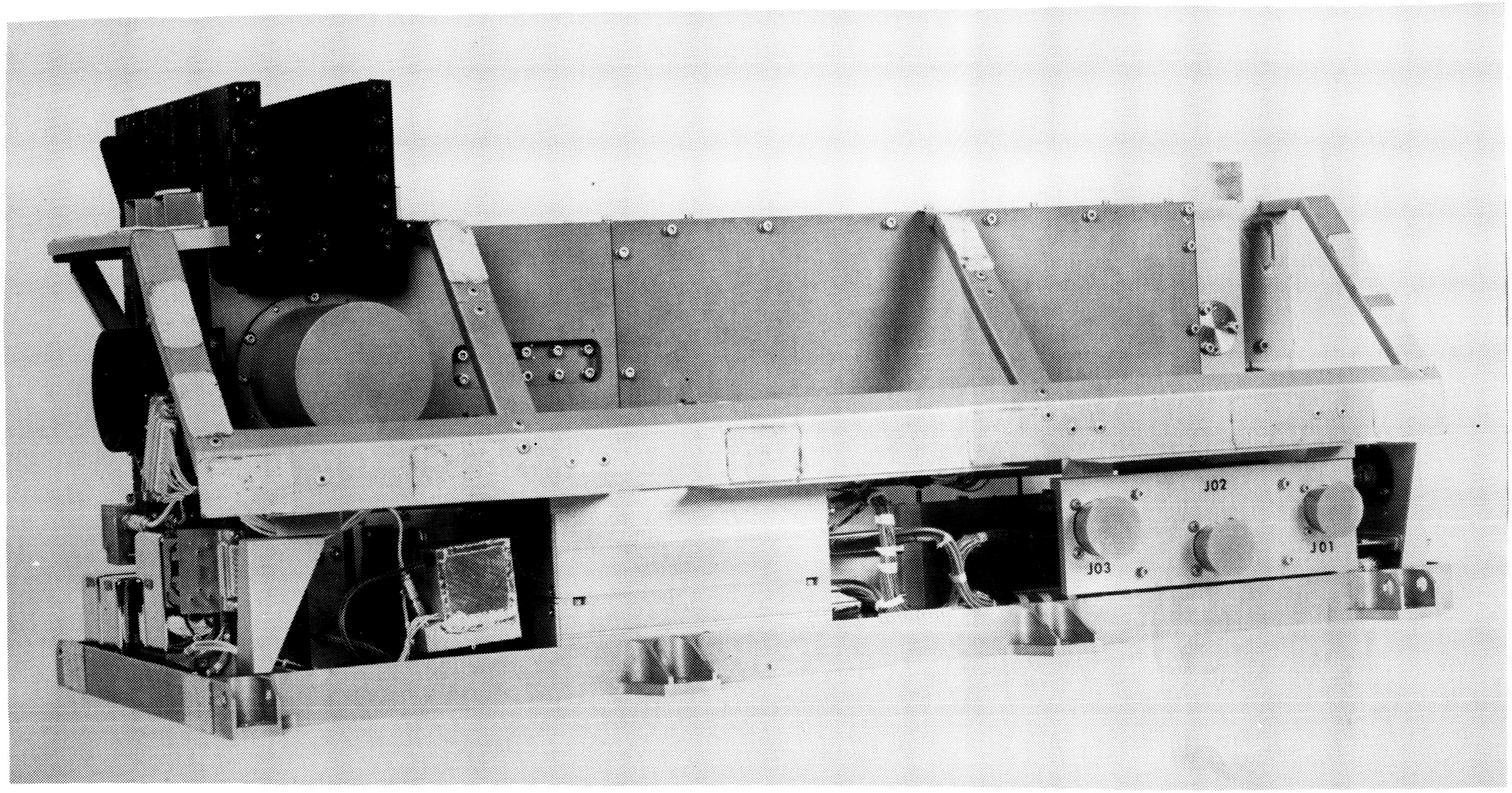

Figure I-2. Photograph of flight instrument.

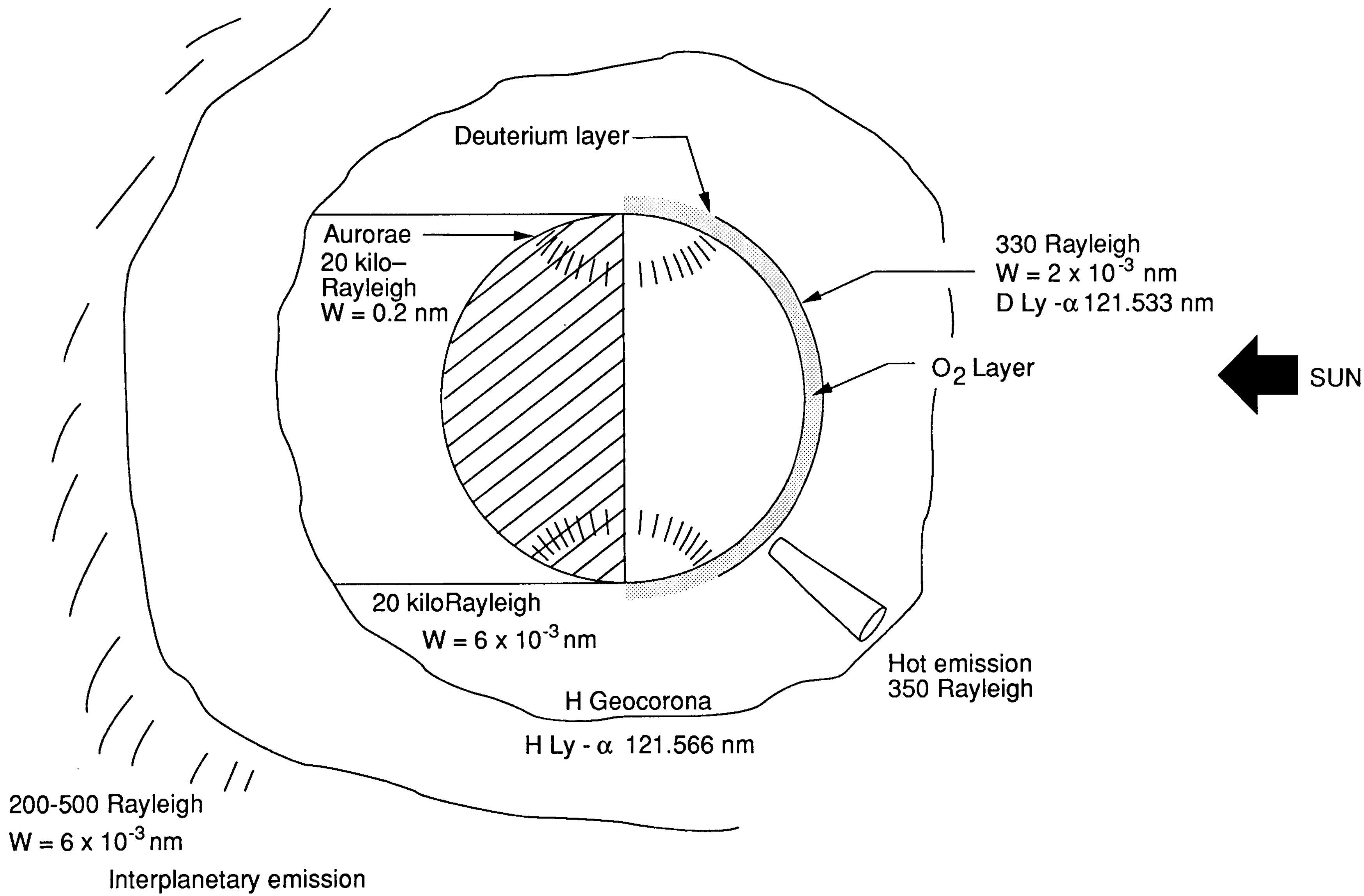

Figure I-3. Emission source for ALAE.

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ATMOSPHERIC TRACE MOLECULE SPECTROSCOPY (ATMOS) (N009)

C. B. Farmer
Jet Propulsion Laboratory, USA

The Atmospheric Trace Molecule Spectroscopy (ATMOS) experiment is a space-borne investigation designed to obtain fundamental information related to the chemistry and physics of the Earth's upper atmosphere (20 to 120 km altitude). The instrument, a high resolution (0.01 cm^{-1}) interferometric spectrometer, measures the atmospheric absorption of solar radiation over the wavelength range from 2 to 16 micrometers, a spectral band which encompasses active transitions of all of the molecular species of current importance in upper atmospheric studies. There are two major aspects to the experiment: the first is the determination of the detailed compositional structure of the stratosphere and mesosphere, and its global, seasonal, and long-term variability. The second is the study of the partitioning of absorbed solar energy at levels in the atmosphere characterized by dissociation of many of the constituents and by the break-down of thermodynamic equilibrium. An added bonus in obtaining the spectra from space at the ATMOS resolution is the ability to extend the frontiers of infrared studies of the photosphere of the Sun.

Since the instrument operates in the absorption mode, measurement opportunities occur twice during each orbit of the Shuttle at the points of apparent sunset and sun-rise. In order to obtain good vertical resolution (2 to 3 km) during these measure-ments, together with the sensitivity to record molecular species at volume concentra-tions as low as parts per trillion, the observations must be made very rapidly and with high spectral information content. The ATMOS instrument is a Fourier transform spectrometer with an aperture of 75 mm and a field-of-view of 1, 2, or 4 milliradians. Solar radiation is acquired and directed into the instrument by a 2-axis sun tracker. A 16-mm camera records the Sun superimposed over the field stop to verify the posi-tion of the pointing vector with respect to the solar disc during each observation. A telescope system is used to concentrate the radiation received into a beam suitable for the interferometer. Cat's-eye retroreflectors replace the plane mirrors used in a conventional Michelson interferometer. A retroreflecting mirror double passes the radiation through the arms of the interferometer before it is recombined and sent to the detector. The use of the cat's-eye retroreflectors and double passing makes the instrument insensitive to both angular and lateral motion of the moving elements. The detector is a HgCdTe type, cooled to cryogenic temperatures. The total optical path difference in the interferometer is ±0.5 m, scanned at a rate of 0.5 m/sec. The inter-ferogram is sampled 400,000 times each second, with a resulting data rate of 16 mega-bits per second. A system controller, which coordinates all instrument functions and operations, formats the data for proper telemetry inputs and provides a responsive interface to the instrument microprocessor. Data taking sequences are normally initiated by a pre-entered command. A compendium of the characteristics of the ATMOS instrument is given in Table I-1.

A dedicated Data Analysis Facility has been developed at JPL to support the reduction and analysis of the large ATMOS data sets. As it is presently configured, this facility is comprised of a Prime 9955 minicomputer with 16 megabytes of main memory, three Floating Point Systems 5205 array processors each with 1 megabyte of random access memory (RAM), two 800/1600/6250 BPI magnetic tape drives, 6 moving head disk drives with a total storage capacity of 5.2 gigabytes, 14 Tektronix Model 4025 graphics terminals, and on-line and off-line copying and plotting capabilities.

An external Shared Access Memory System consisting of 32 megabytes of RAM is attached via high-speed interfaces to each array processor, thus providing the necessary speed and capacity of executing the data reduction and analysis programs in a reasonable amount of time. These programs represent nearly 100,000 lines of code developed for use with the Prime system.

The ATMOS Experiment was flown for the first time on board Spacelab 3 in the spring of 1985, and returned some 20 occultations comprising nearly 2000 spectra from both the northern and southern hemisphere. A partial list of the molecules for which volume mixing ratios were obtained during this flight and the altitudes covered by the measurements is shown in bar chart form in Figure I-5. During the ATLAS missions, similar but more comprehensive data sets are expected to be obtained which will provide the necessary comparisons for the determination of the types of variability mentioned above.

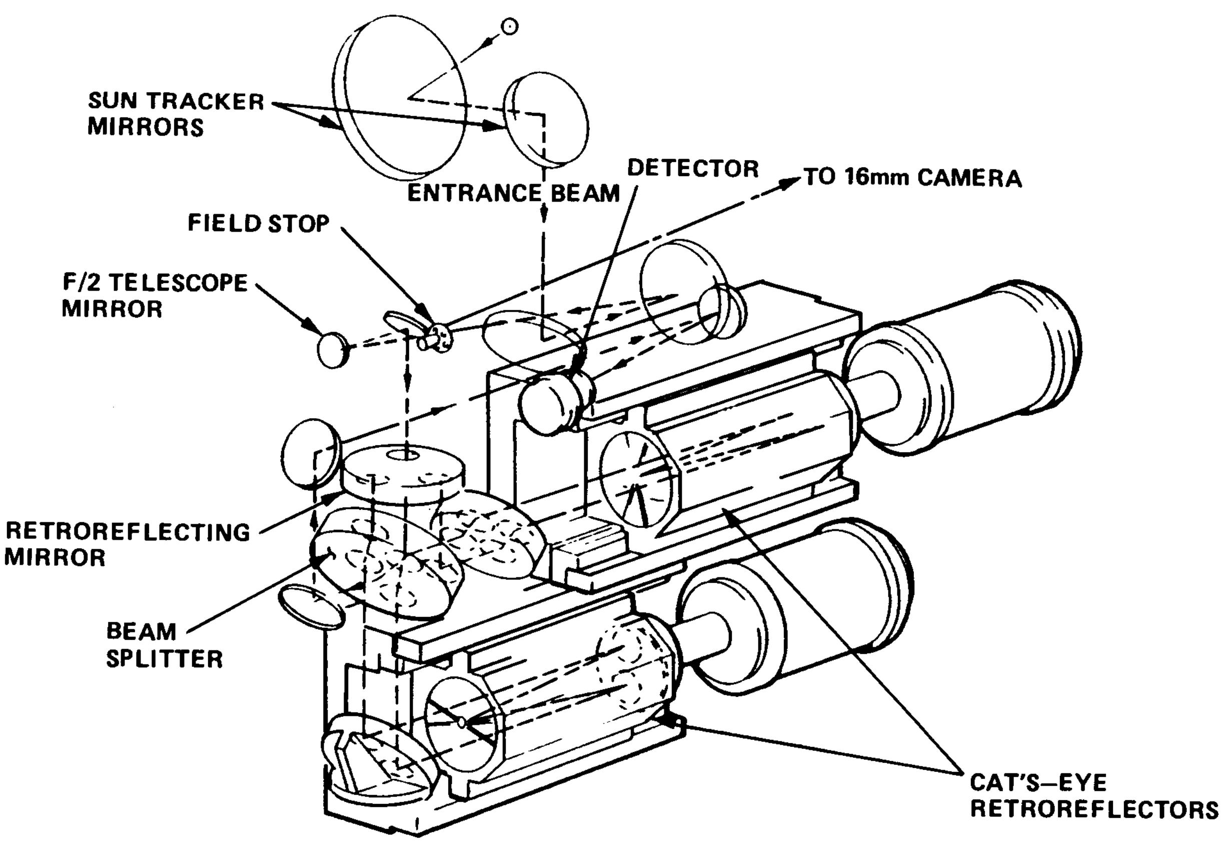

Figure I-4. ATMOS, interferometer optical path.

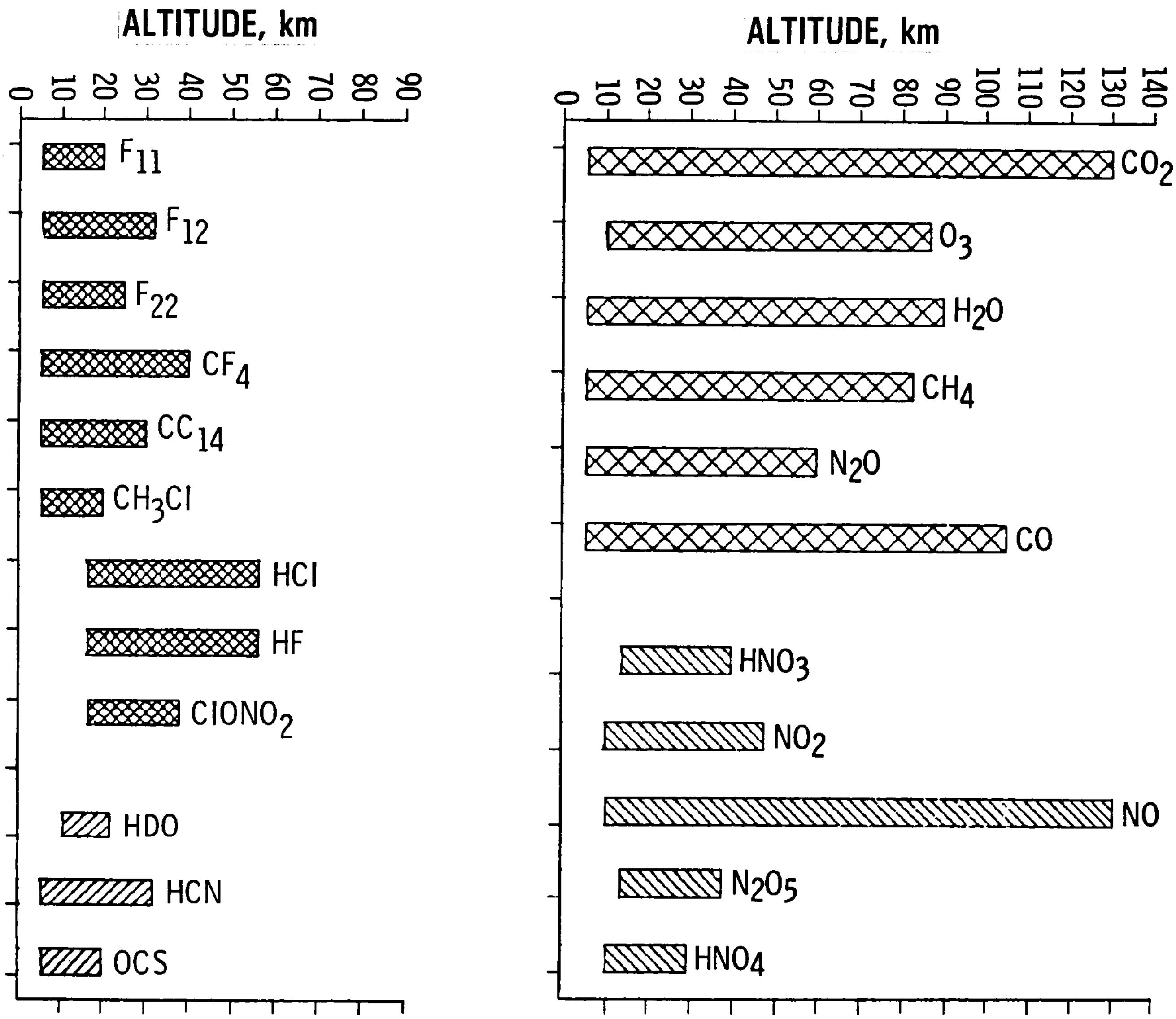

Figure I-5. Species detected by ATMOS on Spacelab 3 and the altitude of the measurements.

TABLE I-1. ATMOS INSTRUMENT CHARACTERISTICS

Spectral Coverage	550-4800 cm^{-1} (2.1 to 18 microns)
Spectral Resolution	0.01 cm^{-1} (unapodised) (50 cm OPD)
Spectral Precision	0.001 cm^{-1} (He/Ne Laser)
Spatial Resolution	2 km
Field of View	Selectable 1, 2, or 4 mrad
Aperture	7.5 cm Diameter
Scan Time	1 sec
Pointing Accuracy	0.1 mrad (2-Axis Suntracker)
Detector	HgCdTe (77°K)
Data Rate	16 Megabits/sec
Mass	250 kgm
Volume	∿1 m Cube (includes electronics and structure)
Average Power	350 Watts

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GRILLE SPECTROMETER (Grille) (E013)

M. Ackerman
Belgian Institute for Space Aeronomy, Belgium

and

J. Besson
Office National d'Etudes et de Recherches Aerospatiales, France

The Grille spectrometer ~~has been~~ designed and flown on Spacelab 1 by two organizations: The Office National d'Etudes et de Recherches Aerospatiales in France and the Belgian Institute for Space Aeronomy in Belgium. Its purpose is to study, on a global scale, atmospheric parameters between 15 and 150 km altitude. The investigation uses high-resolution (better than 0.1 cm^{-1}) spectroscopic observations of the Earth's limb in the wavelength range characteristic of the vibrational-rotational lines of the relevant atmospheric constituents.

The observation of the vertical distribution of molecules from the stratosphere to the thermosphere allows a better understanding of atmospheric chemistry, dynamics, and radiation. Strongly coupled cycles such as the interactions of chlorine or nitrogen compounds with ozone in the stratosphere are influenced by productions and losses taking place at much higher altitudes while the penetrating radiation that promotes photochemical activity depends on the vertical distribution of all atmospheric constituents. Presently, only the lower stratosphere has been monitored on a global scale and that was done by several aircraft campaigns. For the higher stratospheric altitudes, most of the information available has come from balloon flights at the 32°N and 43°N latitudes corresponding to Palestine, Texas, and Aire-sur-l'Adour, France, respectively. For the mesosphere and thermosphere, except for rare rocket flights, the available results have been obtained from spaceborne platforms, most notably, Nimbus 7, Solar-Mesosphere-Explorer, SAGE (Stratospheric Aerosols and Gases Experiment), and Spacelab 1. The weight and power available on the Spacelab pallet permit investigators to fly much heavier instruments than on previous platforms and should permit them to overcome the trade-offs which had to be accepted on lighter satellites. Suitable orbits allow the monitoring of the equatorial and polar regions, together with better-known middle latitudes.

Homonuclear molecules like N_2, O_2, H_2, and rare gases like argon absorb little in the infrared. However, the other minor atmospheric species are very effective absorbants in this spectral range. During its first flight, the grille spectrometer limited itself to ten constituents: O_3, CO, CO_2, CH_4, H_2O, NO, NO_2, N_2O, HF, and HCl. For the ATLAS 1 flight, as the optical characterstics of the instrument have not been modified, this list will be the same except that an observation of lines of the hydroxyl radical OH will be attempted. As during Spacelab 1, small spectral intervals will be used, either preprogrammed in the experiment processor or loaded through commanding or transferred from a Spacelab mass memory unit. During an occultation, different intervals will be scanned depending on limb altitudes. The technological data obtained on the instrument sensitivity during the first flight in real outer space conditions have permitted a reduction in the number of internal contingency spectral windows and an increase in the number of scientific options. The main changes compared to the first flight give a higher priority to spectral lines which

proved to be uncontaminated by solar features as surveyed for the first time during Spacelab 1. Whenever possible, the spectral intervals were broadened in order to gain accuracy by increasing the number of lines used in the interpretations. Intervals in which the signal-to-noise ratio was maximum were also determined in order to lower the detectability limit and to extend the results obtained on Spacelab 1 to even higher altitudes. As an example, absorption spectra showing the growth of water vapor lines in the mesosphere are shown in Figure I-6.

Measurements will also be performed in the emission mode: emissions of molecules that are in excited states and that are located in the mesospheric and/or thermospheric limb will be surveyed at the same 0.1 cm^{-1} resolution as for occultation data.

The grille spectrometer possesses the advantage of a luminosity approximately 25 times better than the conventional slit spectrometer and has the practical advantage of directly recording the spectral information in the very narrow spectral range where this information is relevant. With a classical spectrometer, the entrance and exit slits make the luminosity and resolving power strictly dependent on each other. In fact, high luminosity requires a large throughput for the spectrometer, and a high resolving power requires a large range of transmission for the spatial frequencies in the focal plane of the spectrometer. The instrumental parameters determining these two properties can be made independent by replacing the slits with a plate (grille) that has a large area and a set of alternating reflective and transparent zones, limited by equilateral hyperbolas (Fig. I-7). The grille, acting as a broad bandwidth spatial filter, works by transmission at the entrance and by reflection at the exit. The luminosity depends on the area of the grille, and the resolving power depends on the width of the zones. The actual grille used on the instrument is a 15 x 15 mm square with a minimum step of 0.1 mm.

The resolved spectral signal is selectively modulated by a vibrating collimator that produces a small amplitude oscillation on the dispersed light coming from the spectrometer.

The spectrometer (Figs. I-8 and I-9) operates in the wavelength range from 2.5 to 10 μm. The light coming from the Sun through the Earth's atmospheric limb or from the atmospheric limb itself is reflected toward a telescope by an orientable rectangular plane mirror. The telescope that transmits the light to the spectrometer has a 0.3-m diameter and a 6-m focal length. Two detectors are used simultaneously to cover the entire spectral range. All functions of the instrumentation are programmable through a microprocessor that is a part of the instrument electronics. The instrument is closed when not in operation. A built-in calibration light source allows testing to be performed at any time before and during flight.

The only fundamental hardware change to the Spacelab 1 configuration of the grille spectrometer is the addition of a NASA-provided bottle of pressurized nitrogen to be used for the cryogenic cooling of the detectors. This will allow much longer operation than the internal nitrogen vessel used on Spacelab 1. In addition, an electronics box that was in the Spacelab module will be moved to the pallet.

With these modifications, a comprehensive preplanned geophysical program can be accomplished during the ATLAS 1 mission that will thoroughly address the questions associated with the seasonal and spatial variations of stratospheric, mesospheric, and thermospheric constituents.

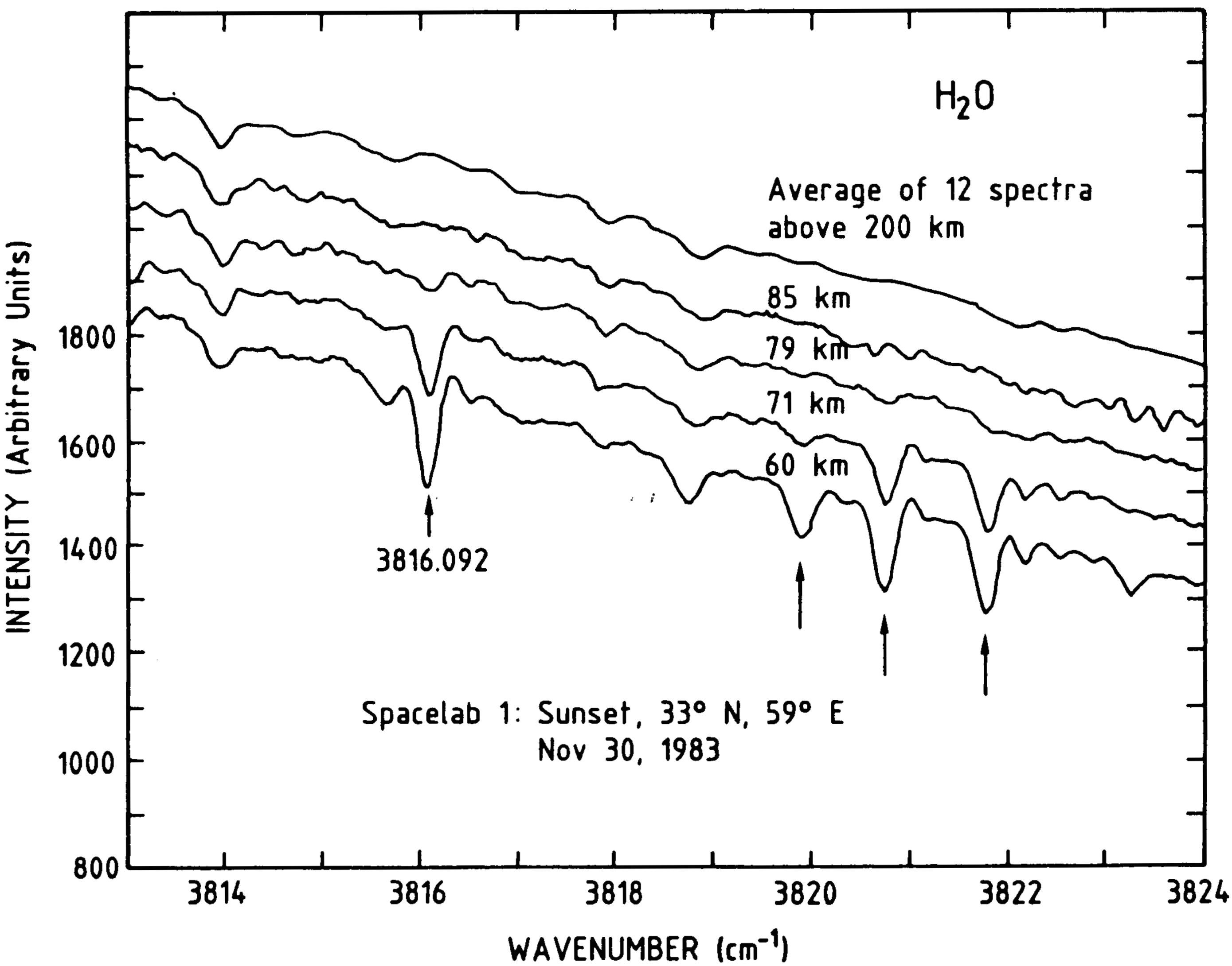

Figure I-6. Spectra of water vapor bands obtained in the range of 2.7 μm as the Sun sets. The upper spectrum is an average of water vapor spectra measured when the minimum altitude of the solar rays is between 200 and 250 km while grazing ray altitudes are indicated on the lower spectra. The strongest H_2O lines have also been indicated.

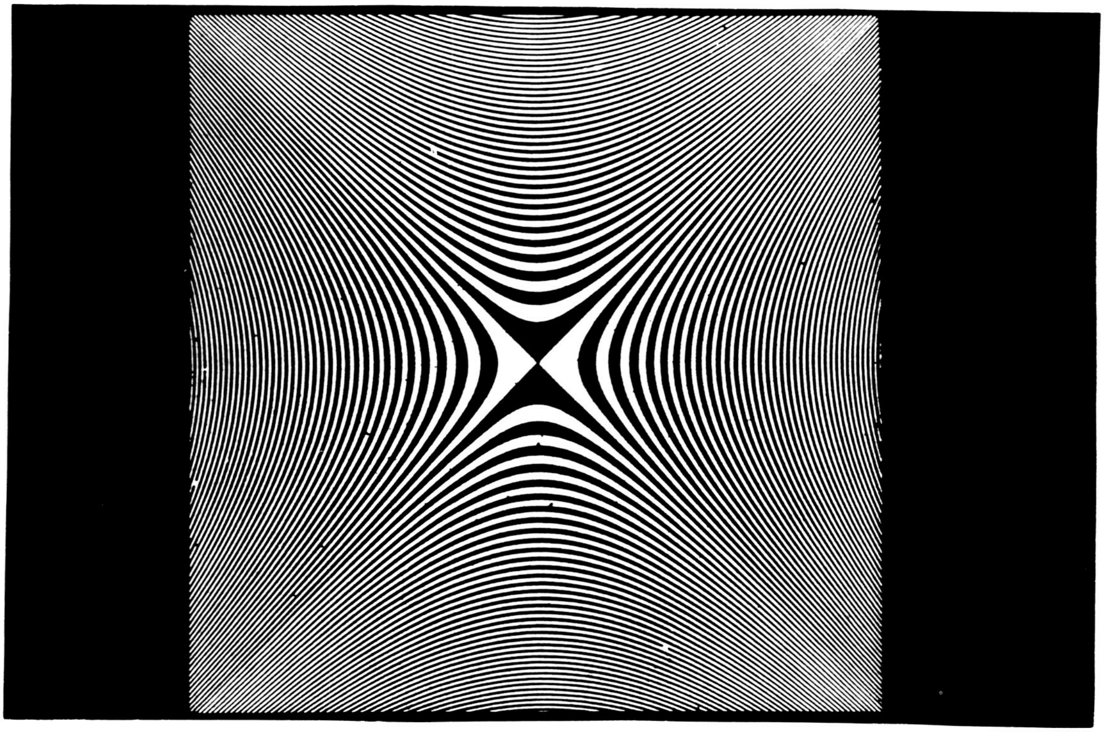

Figure I-7. Drawing of a hyperbolic grille. The minimum step defines the resolution while the luminosity is determined by the entire transmitting surface of the grille.

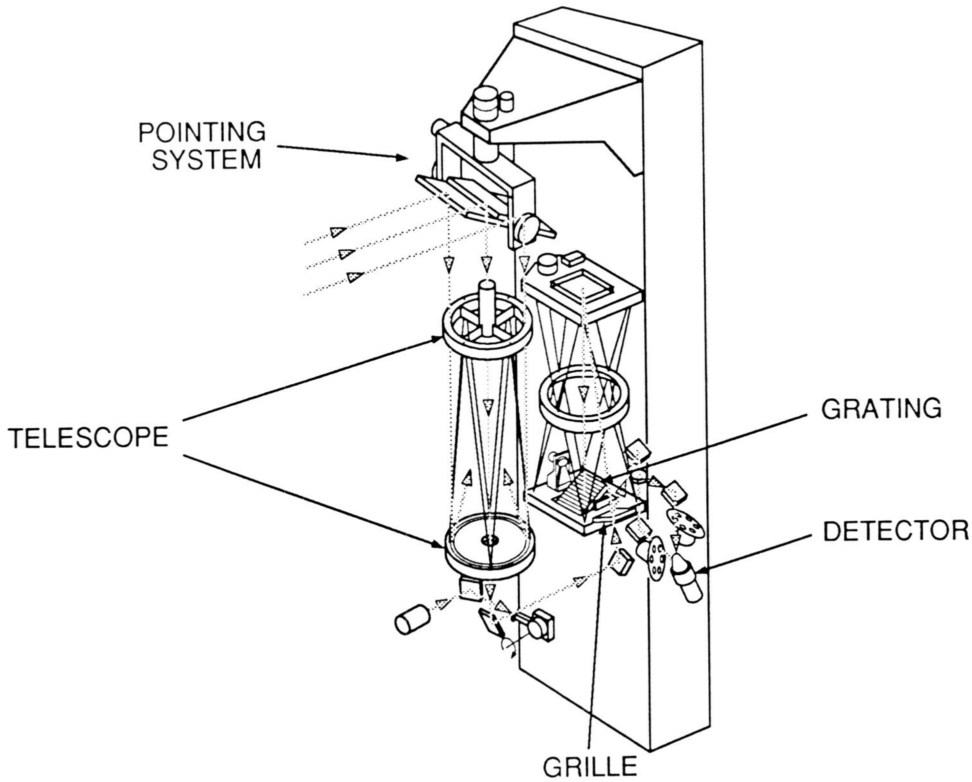

Figure I-8. Optical diagram of the grille spectrometer.

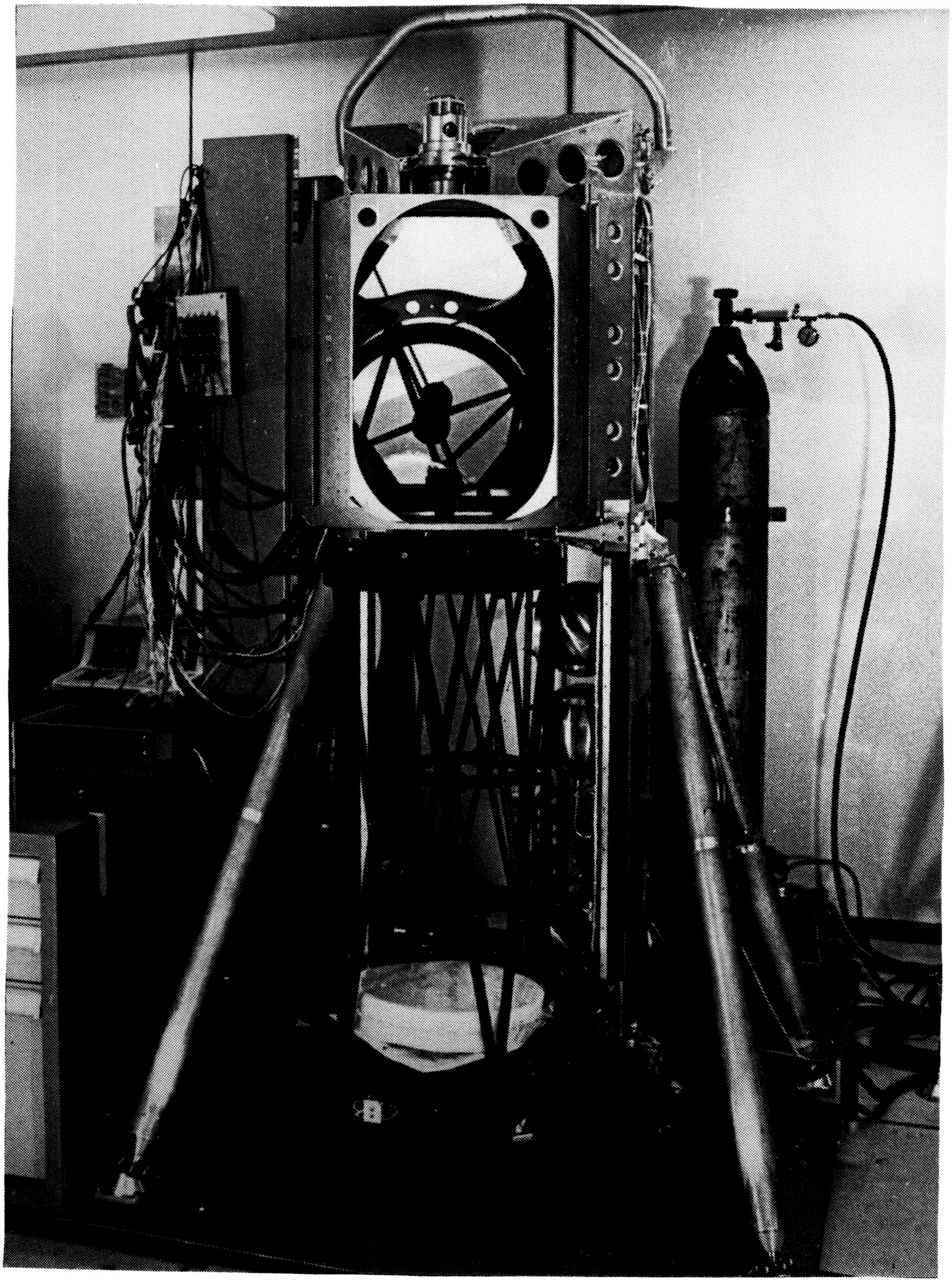

Figure I-9. The grille spectrometer photographed at the ETCA Company in Charleroi, Belgium before final testing at CNES (Toulouse, France), ERNO (Bremen, Germany), and integration of the Spacelab 1 payload at the Kennedy Space Center.

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AN IMAGING SPECTROMETRIC OBSERVATORY (ISO)
(N001)

M. R. Torr
Marshall Space Flight Center, USA

The Imaging Spectrometric Observatory (ISO) has been designed for low light level spectroscopy of both the day and night side of the Earth. The instrument is composed of five spectrometers (Figs. I-10 and I-11), each of which covers part of the total wavelength range of 30 to 1300 nm spanned by the instrument. Wavelength resolution varies between 0.2 and 0.6 nm over the spectral range. The five spectrometers are each optimized for a portion of the spectrum by the choice of mirror reflective coatings and detector photocathode materials. The full spectral range for each spectrometer is covered in a total of 11 grating steps. Some relevant parameters are given in Table I-2.

The five spectrometers operate simultaneously, imaging the spectrum in one dimension and obtaining spatial information (for example, altitude) in the other. This is achieved by means of an intensified-solid state array detector developed especially for this instrument. Each spectrometer has a large dynamic range in signal intensity. Each spectrometer has a 0.65 x 0.01 deg field of view which can be directed at a selected region of the atmosphere either by maneuvering the Shuttle or by means of a scan mirror. Thus, it is possible to obtain spectral data distributed in latitude, longitude, slant path altitude and local time.

The spectrometer array is located on the instrument pallet and a dedicated experiment microcomputer is separately located on the instrument pallet. The microcomputer system controls the instrument observing sequences (scan mirrors, shutters, grating positions, gains), and handles the data compression. It also interacts with the Spacelab computer providing a link between the instrument and the scientists on the ground for direct commanding. In addition, the crew is able to operate the instrument from the Orbiter by using one of the two keyboards on the aft flight deck. Observational sequences can be run from predefined programs stored in the Spacelab system, or entered by the crew or by the scientist on the ground.

The Imaging Spectrometric Observatory was flown for the first time on the Spacelab 1 mission during which it acquired almost 40 hr of observations. This data base has provided the first nearly simultaneously acquired spectra of the thermospheric and mesospheric dayglow over the wide wavelength range of the instrument. These data have provided us with new insights into various atmospheric processes and with surveys of the atmospheric spectrum over a variety of conditions. The information gathered is relevant to the composition and energy budget of the thermosphere, mesosphere, and stratosphere; the solar EUV flux and its influence on the composition and the production of photoelectrons; cross sections for photon and electron ionization and excitation; precipitation of fast charged particles; and the production and loss of various species. An example of one of the novel measurements made by the ISO on the Sapcelab 1 mission is illustrated in Figure I-12. In this sequence, the vehicle was oriented so as to place the spectrometer entrance slit perpendicular to the limb with the center of the slit at 90 km. In this case, the 0.65 deg field of view spanned by the length of the slit subtends approximately 20 km and is resolved into eight adjacent 2.5-km altitude segments from 80 km to 100 km. Thus, in this configuration the entire altitude of the mesosphere is imaged simultaneously. The feature shown is the 1-0 band of the NO gamma system.

The Imaging Spectrometric Observatory investigation to be flown on the ATLAS 1 mission will draw on the experience gained from the data gathered on Spacelab 1. The detector system in each spectrometer has been upgraded to provide both higher sensitivity at low light levels and simultaneous imaging over larger spectral segments than was achieved on Spacelab 1. In addition, the instrument and the observing sequences have been modified to allow observation of the Sun in the extreme ultraviolet. During the solar pointing periods, the ISO will measure the solar spectrum from 30 nm to 125 nm. Rather than concentrating on spectral surveys as was the emphasis for the Spacelab 1 mission, the ATLAS 1 observation sequences have been developed to concentrate on specific scientific issues indicated in the earlier data set.

For example, without the presence of sunlight, oxygen exists in the atmosphere in the form of stable O_2 molecules. When illuminated with ultraviolet sunlight, the O_2 molecules are broken up into highly chemically active oxygen atoms which are capable of initiating and participating in a large number of chemical reactions. The recombination of atomic oxygen forms the protective ozone layer. Recombination of oxygen atoms also returns the original stable O_2 molecules from which the cycle is repeated. These O_2 molecules are returned via various so-called excited states of O_2 which can radiate characteristic emissions. Other chemically active species, such as hydroxyl(OH), are responsible for the removal of ozone molecules. Thus, by simultaneously monitoring the spectral signatures of atomic oxygen at 5577 Å, the various molecular oxygen systems such as the Herzberg and Chamberlain bands in the near UV, the atmospheric bands in the near IR, and the IR atmospheric bands at 1.27 μm, together with the excited OH* bands throughout the visible and near IR, we can obtain a considerable amount of information on this complex photochemistry chain in the mesosphere.

This is one of several such studies for which the ISO will gather the data on the ATLAS 1 mission.

TABLE I-2. SUMMARY OF ISO PARAMETERS FOR ATLAS 1

Spectrometer λ Range (nm)	Spectral Resolution (nm)	Instantaneous $\Delta\lambda$ per Grating Step (nm)	Photocathode	Mirror Coatings
30-125	0.6	18.3	Windowless	Platinum
120-210	0.25	18.3	CsTe	MgF_2
200-410	0.4	24.4	Bi-alkali:S-11	MgF_2
400-800	0.4	49.0	Tri-alkali:S-20	Al/SiO
790-1300	0.6	55.2	S-1	Al/SiO

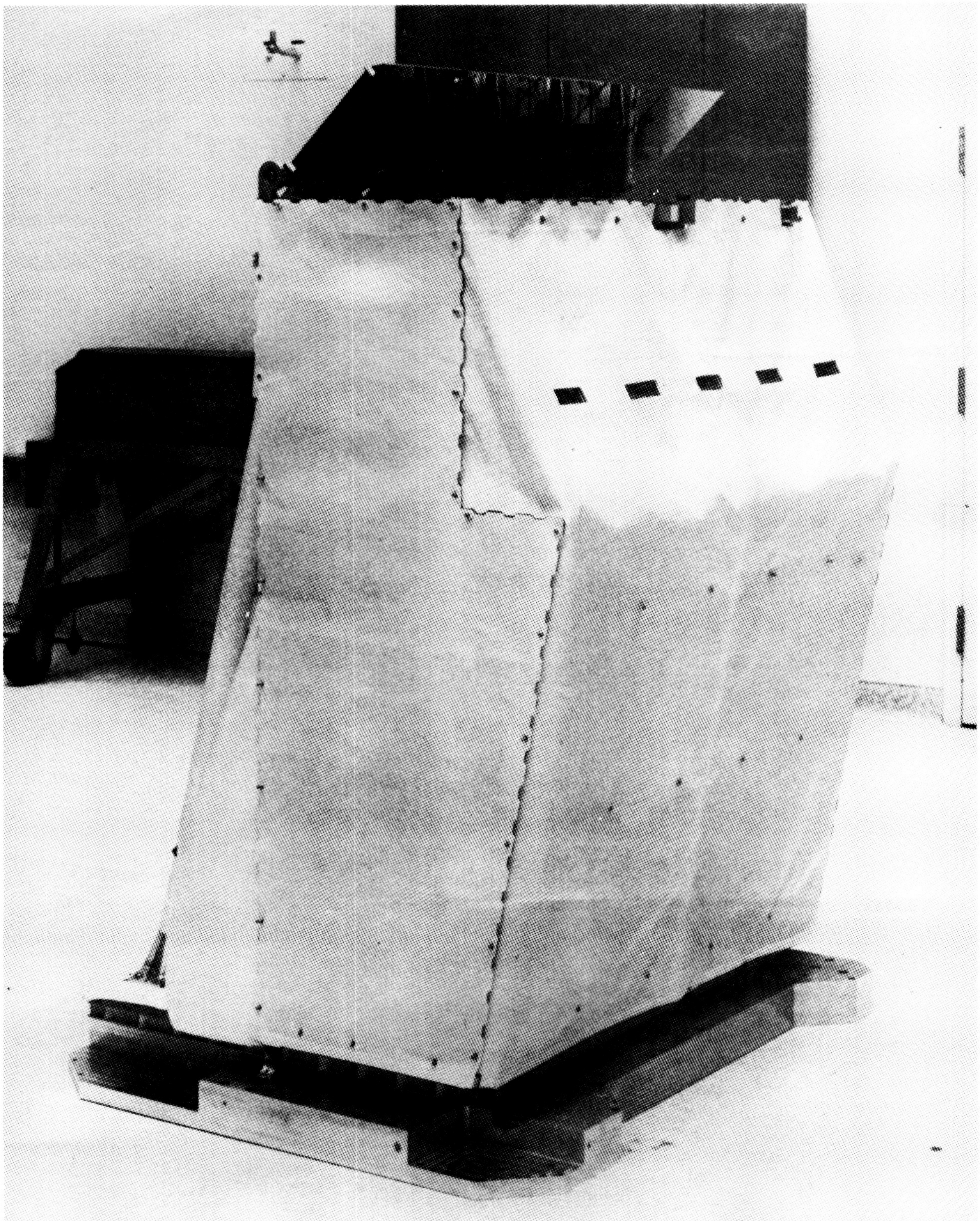
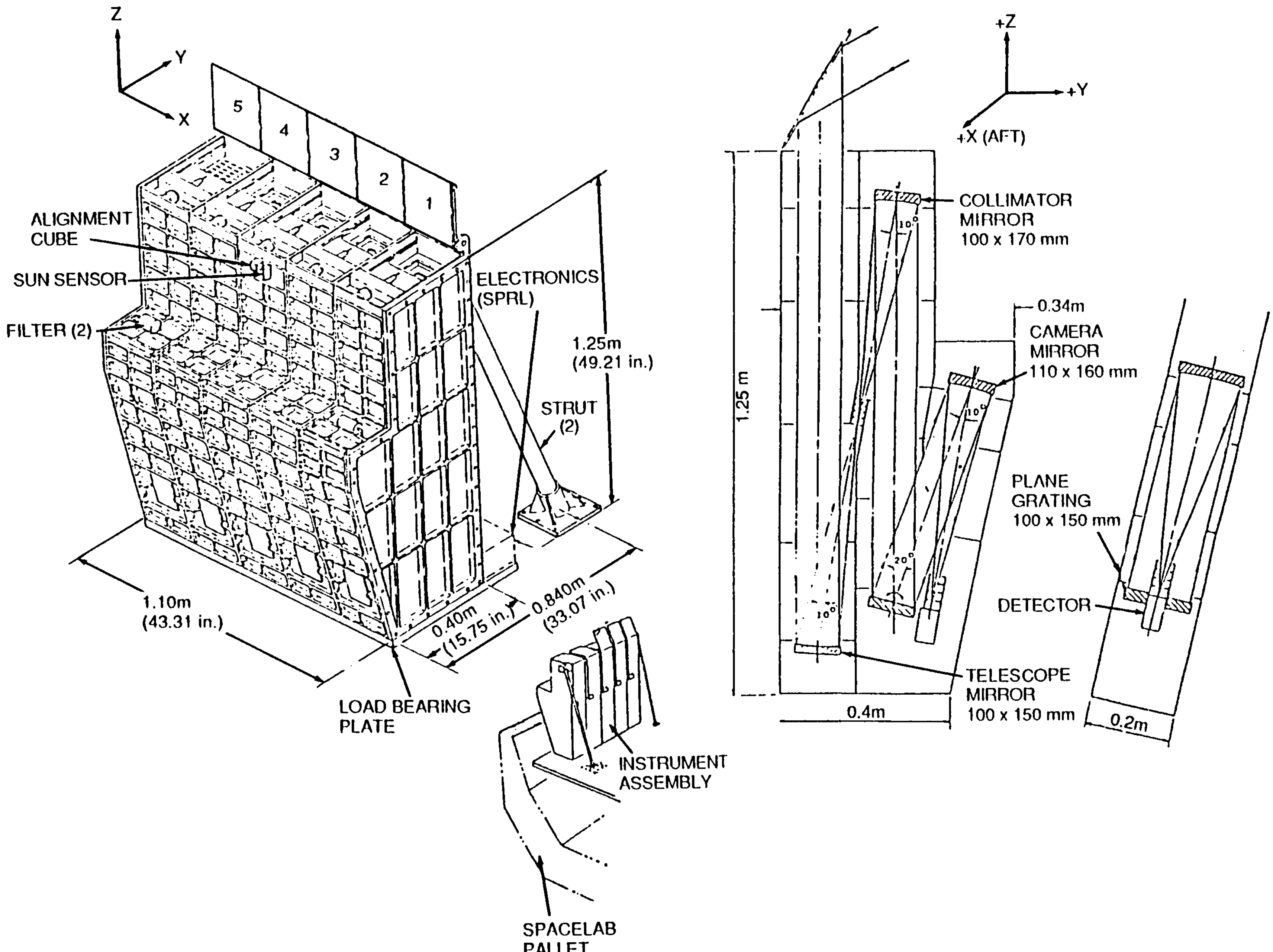


Figure I-10. ISO flight instrument.



(a) Schematic of imaging spectrometer. (b) Optical layout of imaging spectrometer.

Figure I-11. Spectrometer housing and optical layout of all modules except one for EUV measurements.

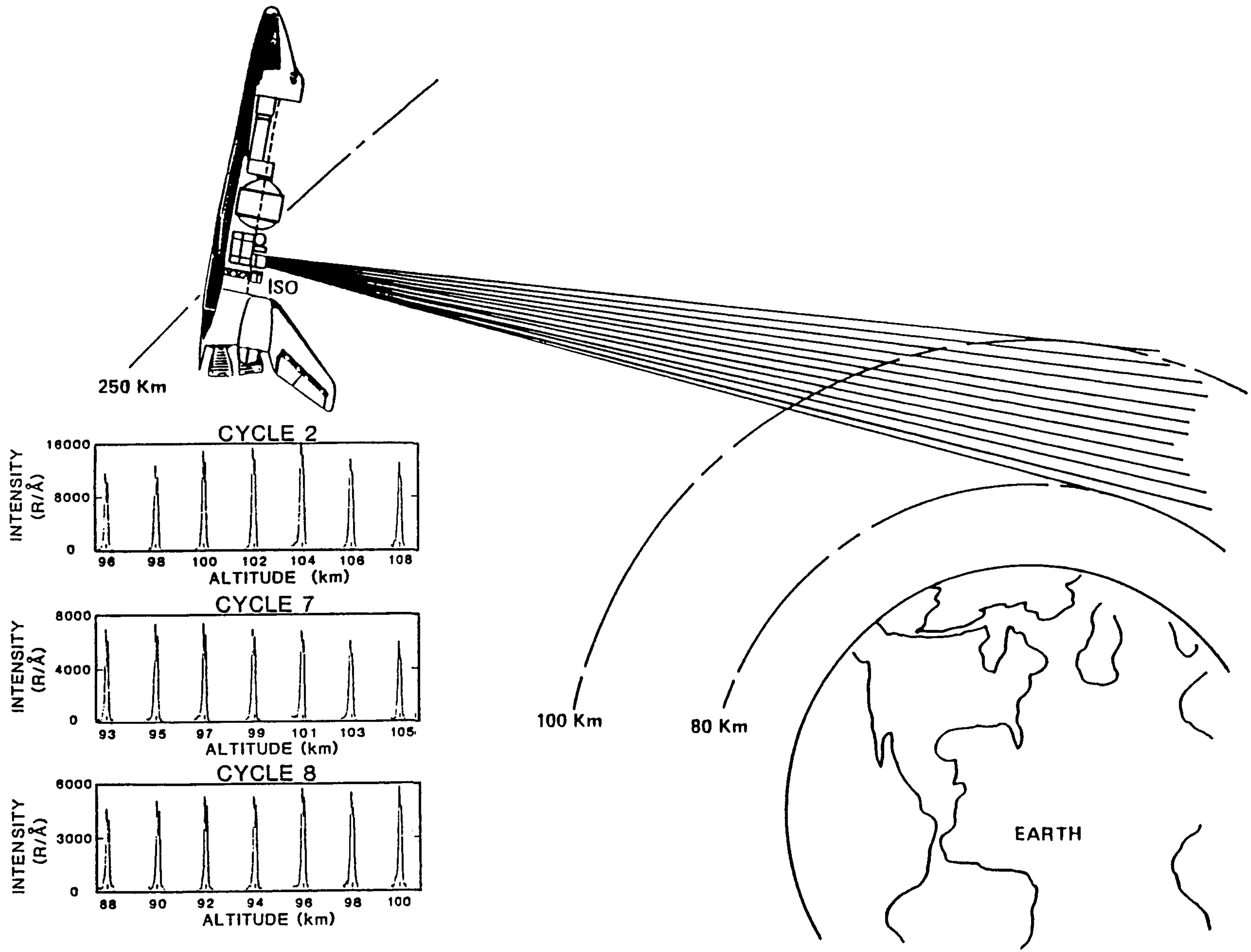


Figure I-12. Illustration of atmospheric measurements made by ISO.

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ENERGETIC NEUTRAL ATOM PRECIPITATION (ENAP)

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The objective of this experiment is to measure very faint emissions at nighttime arising from fluxes of energetic neutral atoms in the thermosphere. These energetic atoms have energies ranging up to about 50 keV, and arise from ions of hydrogen, helium, and oxygen trapped in the inner magnetosphere. Some of these ions become neutralized in charge exchange reactions with neutral hydrogen in the hydrogen geocorona that extends through the region. The ions are trapped on magnetic field lines which cross the equatorial plane at 2 to 6 Earth radii distance, and they mirror at a range of heights on these field lines, extending down to the thermosphere at 500 km altitude.

During magnetic storms the fluxes of trapped particles greatly increase, and their drift motion around the Earth constitutes the ring current. This current of several million amperes is one of the major elements of the magnetospheric current system detectable as a worldwide magnetic storm.

The energetic neutral atoms (produced when the ring current ions undergo charge exchange) travel on straight line trajectories, and the spray of neutrals impacts the thermosphere at low, middle, and high latitudes, as well as traveling freely through interplanetary space. Figure I-13 illustrates the geometry of the process. During magnetic storms, detection of these energetic neutrals by instruments on the IMP and ISEE spacecraft in interplanetary space has allowed a primitive image of the ring current to be made. Prospects are very good for high quality images to eventually be made with specialized instruments, which will show the distribution of H^+, He^+, and O^+ and their energies, as well as the location and the nature of the growth and decay of the ring current.

The ATLAS 1 measurements will not be of the neutral atoms themselves but of the optical emission produced by those on trajectories that intersect the thermosphere. At middle and high latitudes during magnetic storms the energetic neutrals will be accompanied by ions dumped directly from the ring current if the configuration of electric and magnetic fields in the magnetosphere is such (as it often is during the initial phases of magnetic storms) that the mirror height of the ions is lowered into the dense thermosphere below 500 km. When the processes which lower heights cease, the charge exchange at heights out to several Earth radii continues to produce the spray of energetic neutrals into interplanetary space and the thermosphere. Even under quiet magnetic conditions, small fluxes of energetic neutrals will be present.

In the thermosphere, the directly precipitated ions are likely to charge exchange and become neutrals, and some neutrals are likely to become re-ionized in collisions with thermospheric constituents. The net result of precipitation of either energetic neutrals or ions after the first few collisions in the thermosphere is a flux of energetic neutrals and ions (mostly neutrals) that produce optical emission, ionization, and heating of the thermospheric constituents.

The optical emission is one component of low-latitude aurorae that have distinctly different spectral properties from the normal polar aurora that is excited by kilovolt electrons. A characteristic of collisional excitation by heavy particles is that they transfer momentum and excite vibrational and rotational levels of molecules.

Thus, high vibration and rotational excitation levels of ionized molecular nitrogen (the N_2^+ 1N bands) is a signature of hydrogen atoms or protons with energy below 2 keV, of helium ions with energy below 8 keV, and of oxygen atoms or ions with energy below 30 keV. Other characteristics include Doppler broadened lines of H, He, and O. At times the low-latitude aurorae show a brilliant red color due to atomic oxygen (6300 Å) emission. This is not due to the energetic neutral atoms and ions, but rather to large currents of low-energy electrons (about 1 eV) which at times accompany the development of the ring current. When the low-energy electrons are absent, the aurora has a whitish color.

The ENAP measurements are to be made using the Imaging Spectrometric Observatory (ISO) that was designed and built by Marsha Torr. The ISO is being flown on the ATLAS mission primarily for daytime spectral observations, and the ENAP measurements will all be nighttime measurements because of the faintness of the emissions and the relatively low level of magnetic activity expected. Only in major magnetic storms does the emission become bright enough to be visible to the naked eye. The observations from orbit will be able to detect much fainter emissions than from the ground, owing to the sideways view through the emitting layer, the lack of the foreground of brighter airglow emissions at lower altitudes, and the very high sensitivity of the ISO instrument itself. From the latitude and time variations of different emissions, we hope to better understand the nature of neutral atom precipitation, its effects on the thermosphere, and the possibilities for future use of the phenomenon for imaging the ring current.

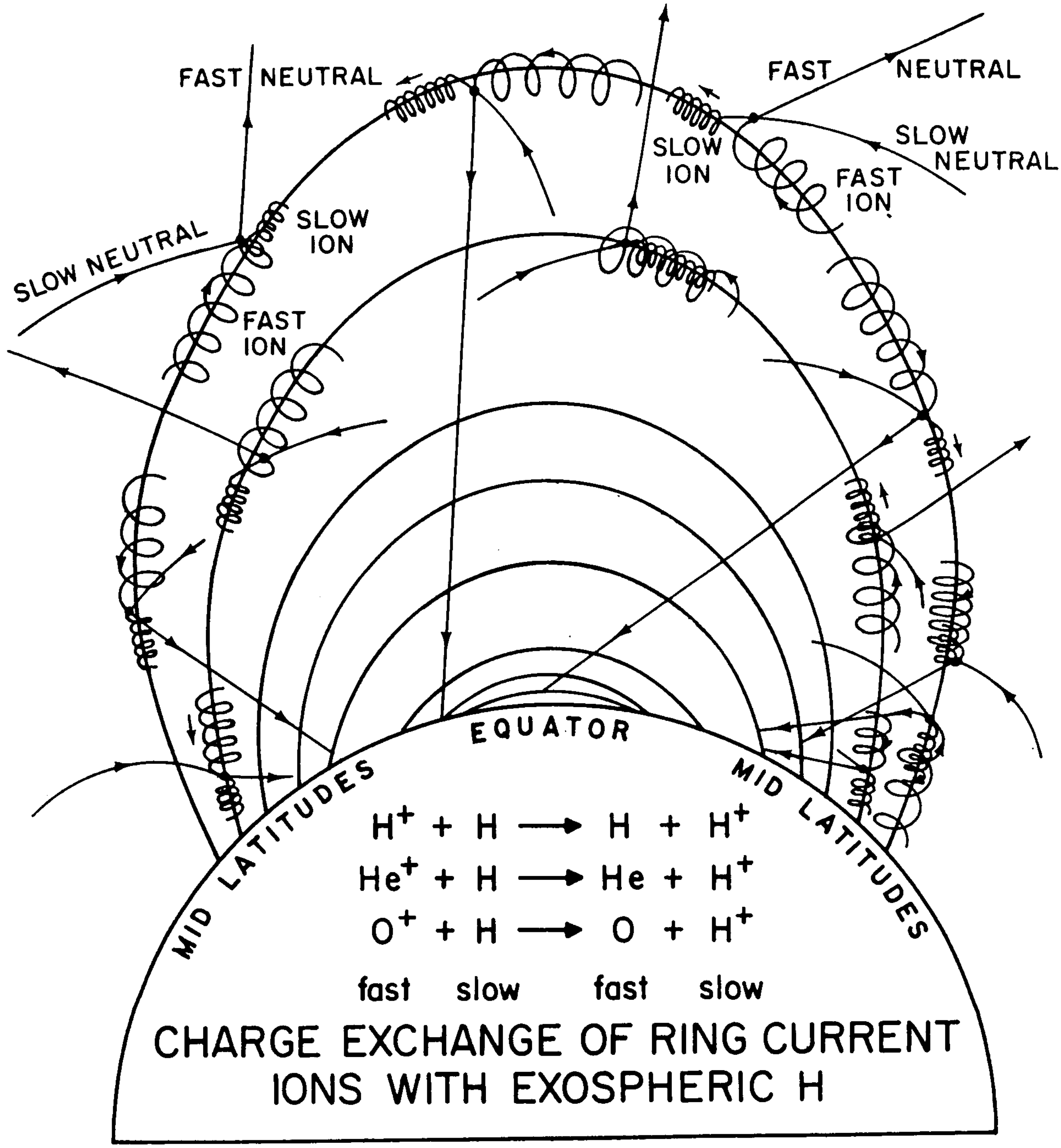

Figure I-13. Geometry of the production of energetic neutral atoms of H, He, and O from the corresponding trapped ions H^+, He^+, and O^+ in the ring current.

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MILLIMETER-WAVE ATMOSPHERIC SOUNDER (MAS)
(E034)

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MAS is a remote sensing instrument for passive sounding (limb sounding) of the Earth's atmosphere from Space Shuttle. Millimeterwave radiation emitted by the atmosphere in the height range between 20 km and 100 km will be measured at 61, 62, 63, 183, 184, and 204 GHz with a height resolution as low as 4 km.

MAS data yield direct information about the altitude distribution of temperature (T), pressure (P), water vapor (H_2O), ozone (O_3), and chlorinemonoxide (ClO) in the atmosphere and mesosphere, over the latitude ranges ±45 deg or ±74 deg depending on the Shuttle mission (28 or 57 deg orbit inclination).

Besides new information for basic research (geophysics), MAS can be regarded as an early warning system for important environmental effects, e.g., the man made (anthroprogenic) destruction of the ozone layer.

MAS is a passive total power microwave radiometer-spectrometer for Earth limb observations from space. It measures the radiation emitted by various constituents in the atmosphere of the Earth.

The millimeter wave radiation from the Earth's limb is collected by a steerable parabolic antenna (ANT), consisting of a 1-m diameter main reflector and a smaller sub-reflector, and the radiation is focused into the MAS Receiving Electronics (MRE) (Figs. I-14 and I-15). The antenna positioning in elevation over a range of about 4 deg within a total scan range of 13 deg is done by a linear actuator. The position angle is measured by a resolver and is fed into the MAS Control Electronics (MCE). It controls the linear actuator's positions which are commanded by the Data Electronic Box (DEB). The antenna scan can be selected from several modes.

The MRE consists of three radiometers denoted as channel 1 through 3. Channel 1 operates at 61 to 64 GHz, channel 2 at 183 GHz, and channel 3 at 204 GHz (Table I-3). They down convert the signals to several intermediate frequencies (IF) below 6 GHz. These IF signals are fed through appropriate flexible connections to the Filter Electronic Box (FEB) where they are analyzed in five filterbanks consisting of 240 filters with bandwidths of 200 KHz, 2 MHz, and 40 MHz. The filters are followed by quadratic detectors, multiplexer, and A/D converters. The FEB furthermore contains a programmable frequency synthesizer for compensation of the Doppler shift.

The FEB communicates with the DEB that receives its data. All data telecommand execution and data handling is performed in the DEB. Based on attitude and orbit information available in real time (GN&C and Horizon Sensor Data), the DEB also checks on the antenna position.

The DEB formats all data including housekeeping information and transmits it to a HRM channel of the Shuttle's CDMS at a data rate of 86.4 kBit/s. The DEB also contains the MAS power supply.

The main objective of the MAS is to study the composition and dynamic structure of the stratosphere, mesosphere, and lower thermosphere in the height range 20 to 100 km, the region known as the middle atmosphere.

Clearly, global observations are of paramount importance in order to establish a data base for validating results from both one-dimensional and multi-dimensional photochemical models.

Two crucial parameters to be measured in the stratosphere and mesosphere are ozone concentrations and temperature. Temperature is important for many reasons. Using temperature and pressure data, the distribution of the geostrophic wind can be determined, which is a close approximation to the prevailing wind at stratospheric levels outside the tropics. Many important chemical reactions are temperature dependent, so that the temperature must be known before the chemical production and loss rates of several stratospheric constituents can be determined. The stratospheric temperature is also important in determining the exchange of infrared radiation with the troposphere below, with atmospheric regions above, and with space.

Ozone is important because of its effect in shielding the biosphere from harmful ultra-violet radiation and because it plays an important role in absorbing solar radiation and in absorbing and re-emitting infra-red radiation. It therefore plays a crucial part in determining the distribution of stratospheric heat sources and sinks, and thus helps to determine stratospheric temperature and wind structures. Further, since in the stratosphere O_3 is chemically longlived, it can be used as a tracer of atmospheric motions. Recent work on the photochemistry of ozone shows that there are still many important uncertainties in the chemistry, even though O_3 has been much studied.

There is much concern that the effects of chlorofluoromethanes (CFMs) and related chemicals in the atmsophere, which produce chlorine radicals, such as ClO, in the stratosphere may be deleterious to the ozone layer. Such is the uncertainty of these effects that the steady state depletion of ozone by CMFs is unknown by a factor of two, due to the crude treatment of transport alone. To date, there have been very few measurements of upper atmospheric ClO, with results varying by nearly an order of magnitude, and with no information on latitudinal variations. Clearly, global data on ozone and ClO, the most important product in the catalytic destruction of ozone by chlorine, will provide answers to the problem of anthropogenic influences on the ozone layer.

Photochemical models show that H_2O plays a central role in controlling the distribution of O_3 through odd hydrogen reactions. Water vapor, in addition, is a valuable tracer of vertical transport in the upper stratosphere and mesosphere and is energetically the most important gas, playing a major role in irreversible thermodynamic processes.

In contrast to the molecules mentioned above, the oxygen molecule (O_2) has no electric dipole moment but does have a magnetic dipole moment. All O_2 resonances below 300 GHz are fine structure transitions between different orientations of the electron spin and the molecular rotation. Since in the atmosphere O_2 has a constant mixing ratio up to about 90 km, the measured thermal radiation can be used to determine the atmospheric temperature profile. Furthermore, since some of the higher rotational transitions are temperature dependent while the line width is pressure dependent, emissions from those lines can be used to derive atmospheric pressure profiles.

At altitudes above about 15 km (pressure $<$ 100 mb), most molecular resonance lines are well separated at microwave frequencies. Since coherent microwave receivers

are capable of virtually infinite spectral resolution, the line shape can be measured accurately to very high altitudes (80 to 120 km, depending on line strength). Further, the microwave transitions of oxygen remain in local thermodynamic equilibrium up to altitudes over 90 km, allowing temperature measurements to be made up to these altitudes.

The Millimeter-Wave Atmospheric Sounder will provide, for the first time, information obtained simultaneously on the temperature and on ozone concentrations in the 20 to 90 km altitude region. The information will cover a large area of the globe, will have high accuracy and high vertical resolution, and will cover both day and night times. Additionally, data on the two important molecules, H_2O and ClO, will also be provided.

TABLE I-3. PARAMETERS AND CONSTITUENTS MEASURED BY MAS

Frequency (GHz)	Parameter/ Constituent	Height Range (km)	Accuracy	Integration Time (s)
Channel 1				
61,151	Kinetic Temperature	20 - 100	2°K	2-10
62,998	Pressure	35 - 70	1%	2
63,568	Pressure	35 - 70	1%	2
Channel 2				
183,31	Water Vapor	20 - 90	2×10^{-7} VMR*	2-100
184,37	Ozone	20 - 90	2×10^{-7} VMR	2
Channel 3				
204,35	Chorinemonoxide	30 - 45	2×10^{-10} VMR	100

* VMR: Volume Mixing Ratio

ANT Antenna System
SPM Scan and Pointing Mechanism
MRE MAS Receiving Electronics
FEB Filter Electronics Box
DEB Data Electronics Box
MCE MAS Control Electronics

Antenna-Diameter : 1.0 m
Spectral Resolution : 240 Channels (12 bit)
Datarate : 86.4 kBit/s
Power Consumption : 420 W
Mass : 167 kg
Dimensions((LxWxH) : 120 x 130 x 170 cm

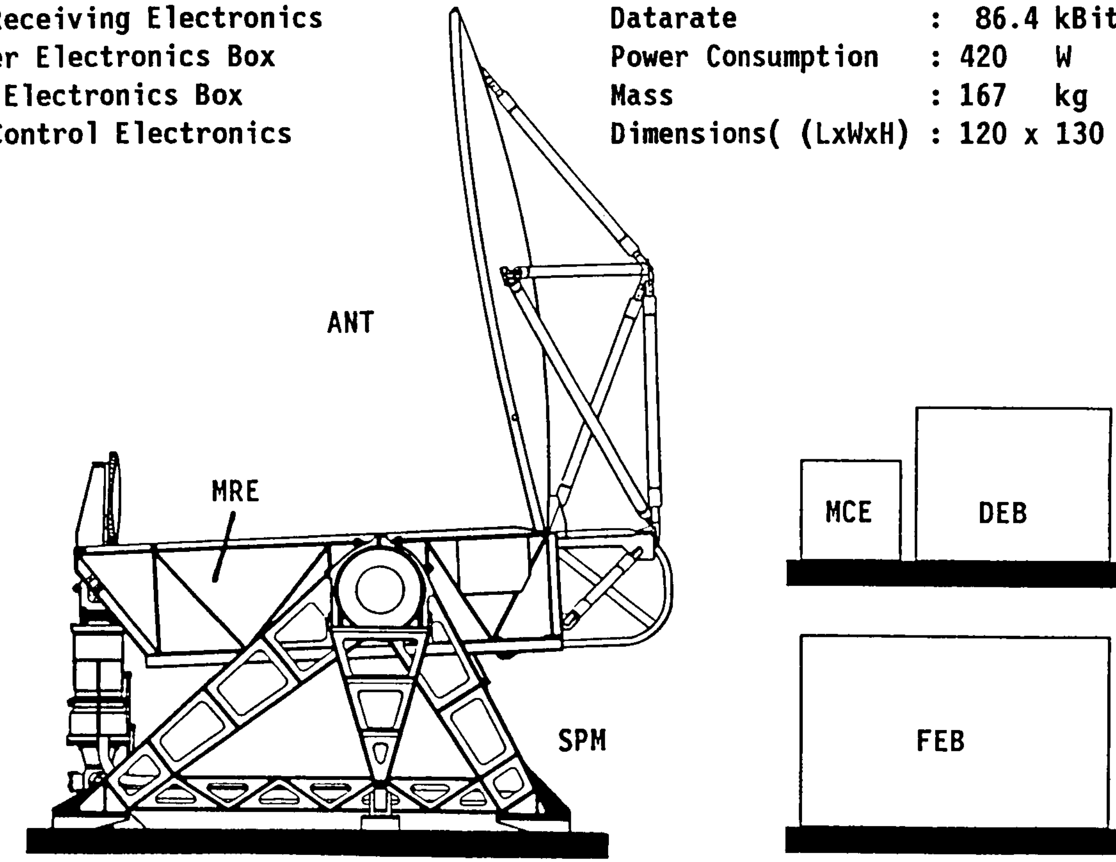

Figure I-14. MAS schematic configuration.

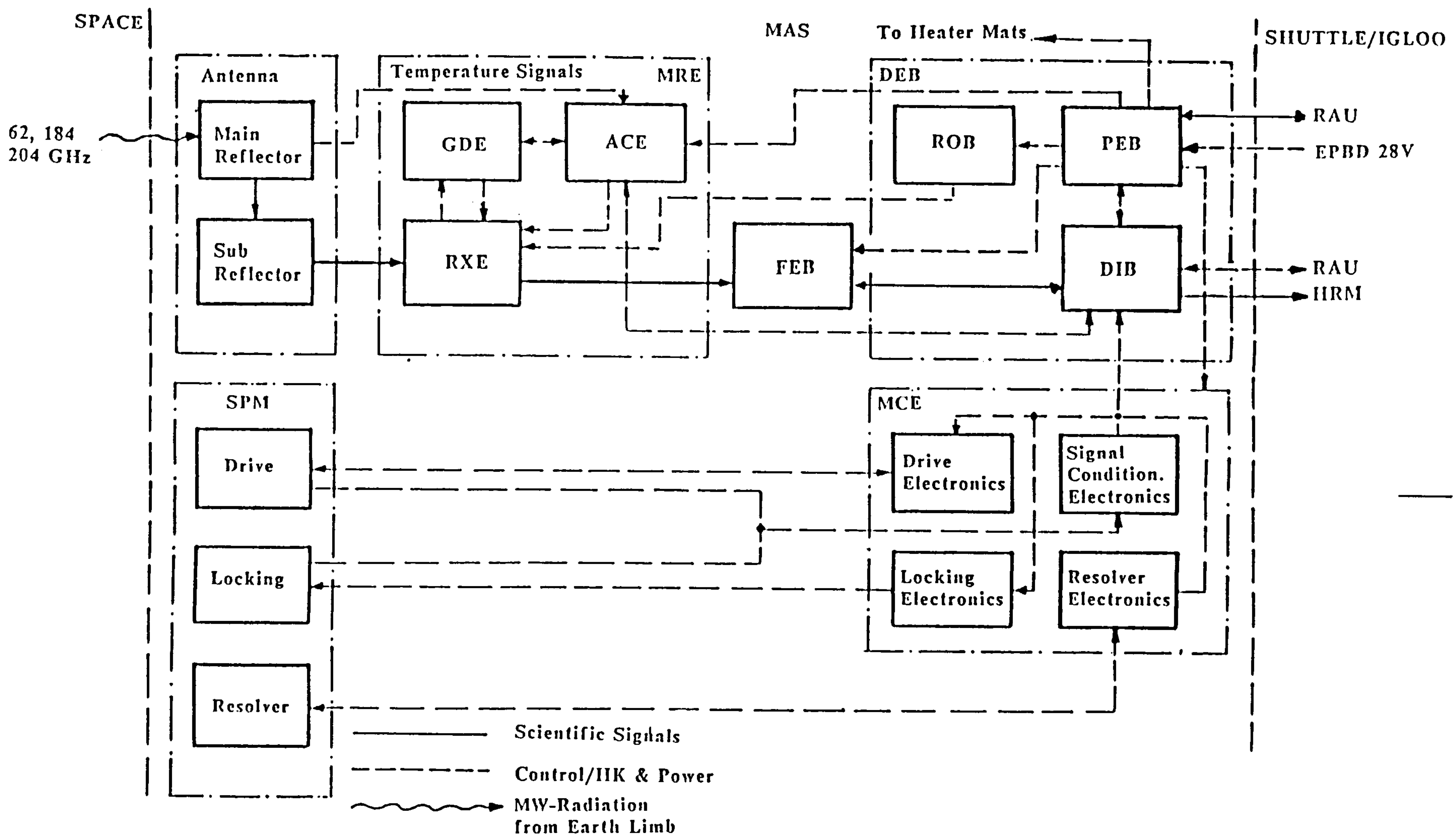

Figure I-15. MAS functional block diagram.

SECTION II

SOLAR PHYSICS

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38.

ACTIVE CAVITY RADIOMETER (ACR)
(N008)

R. C. Willson
Jet Propulsion Laboratory, USA

The objective of the Active Cavity Radiometer (ACR) experiment on the ATLAS mission is the measurement of the total solar irradiance with state-of-the-art accuracy and precision. This experiment is part of an ongoing program of space flight observations to study short- and long-term variations in the total solar output of optical energy. Precise observations of solar total irradiance provide information on the solar cycle and other long-term trends in solar output that are of climatological significance as well as short-term solar physics phenomena such as radiation anisotropy, active region structure, "missing flux" due to sunspots, bolometry of solar flares, global oscillations, coronal holes, and large-scale convective flows.

The interaction of solar radiation with the Earth's atmosphere, oceans, and land masses provides the primary driving force for the formation of weather systems and the determination of climate. Small changes in the solar luminosity could have far-reaching implications: systematic changes of only 0.5 percent per century could explain the entire range of past climate from tropical to ice age conditions.

The determination of the total energy flux is one of the most basic measurements of astrophysics. Its average value gives the solar luminosity, and variations around the average can arise from intrinsic variations in energy generation or transport within the solar interior, or solar atmospheric phenomena of several kinds.

The principal role of the ATLAS ACR observations will be in support of extended solar irradiance experiments on free-flying satellites. Annual in-flight comparison of observations by both ATLAS and free-flying experiments is an important part of sustaining the long-term precision of the climatological solar irradiance data base at the required ±0.1 percent level.

A second important role for ATLAS solar irradiance measurements will be establishment of the radiation scale at the solar total flux level in the International System of Units (SI). Two types of pyrheliometers, the ACR and SOLCON (see the E021 description), will be directly intercompared during the ATLAS 1 mission. Addition of other sensors is planned for future reflights. Comparisons of solar observations by different pyrheliometers in the shuttle space environment will provide the most definitive experiment for determining their accuracy in defining the radiation scale at the solar total flux level.

The ACR instrument on the ATLAS 1 mission consists of three independent, self-calibrating cavity pyrheliometers (Fig. II-1). Their active cavity radiometer (Type V) sensors are the most recent in a series developed at the Jet Propulsion Laboratory for defining solar radiation measurements in the International System of Units (SI).

The name Active Cavity Radiometer characterizes the mode of operation of these pyrheliometers. A servo system maintains the temperature of the primary (solar viewing) cavity 0.5 K above that of the reference cavity by controlling the electrical power supplied to its heater. As the shutter alternately blocks or admits solar irradiance to the cavity through its 10 deg field-of-view, the servo system adjusts

the power accordingly, and the difference between shutter open and closed is proportional to the solar irradiance. The constant of proportionality is determined from accurate measurements of the electrical properties of the cavity heater, the area of the precisely machined aperture through which the solar irradiance enters the cavity, and the absorptance of the cavity for the solar flux. Each of the three ACR V sensors is an independent, electrically self-calibrated pyrheliometer, with an effective thermal time constant of 1 sec.

The spectral bandpass of the ACR sensors is determined by the efficiency of the specular black absorber on the inner face of the primary cavity. The specular finish guarantees multiple interactions between the incident radiation and the cavity absorbing surface. Reflectance measurements made by the National Bureau of Standards indicate an effective cavity absorptance for the ACR V of 0.999880 ± 0.000020 in visible light. Uniform response for the cavity with an effective absorbance near this value is predicted from the vacuum UV to the mid-IR.

Separate shutters on each sensor facilitate their operation with different frequencies for all possible combinations in either automatic or manual modes. The three sensors are used in various combinations to provide periodic cross references on the system's performance. This phased use of the three channels is designed to sustain maximum precision and accuracy of the ACR's observations for the duration of the mission.

The ACR system is modular in design for maximum flexibility as a reflyable solar irradiance experiment. In Figure II-2 the basic system components are shown as the electronics, sensor, shutter, and ACR (detector) modules. Up to six detector modules of the configuration shown in Figure II-1 can be flown using the four cylindrical mounting bays and adding two more to the rectangular bay of the sensor module. Three ACR V's will be flown on the ATLAS 1 mission. The fourth cylindrical bay will house a Sun position sensor designed to measure the relative angle between the instrument axis and the solar vector. In future reflights, as the complement of sensors increases, the Sun sensor will be mounted externally on the sensor module's alignment pad.

Analysis indicates the ACR V is capable of defining the radiation scale with ±0.1 percent SI uncertainty. Determination of the actual level of performance in flight will be the object of a series of in-flight intercomparison experiments that began with Spacelab 1. The single sample irradiance precision will be ±0.012 percent. The 1σ uncertainty for a single measurement cycle ($\sim$2 min) is expected to be less than ±10 ppm.

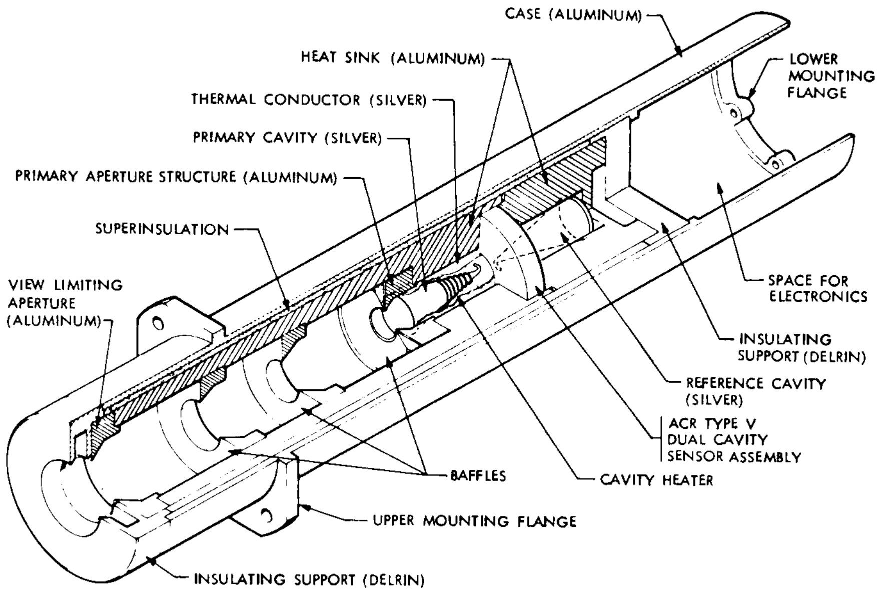

Figure II-1. Schematic of Jet Propulsion Laboratory's ACR Module (Type V).

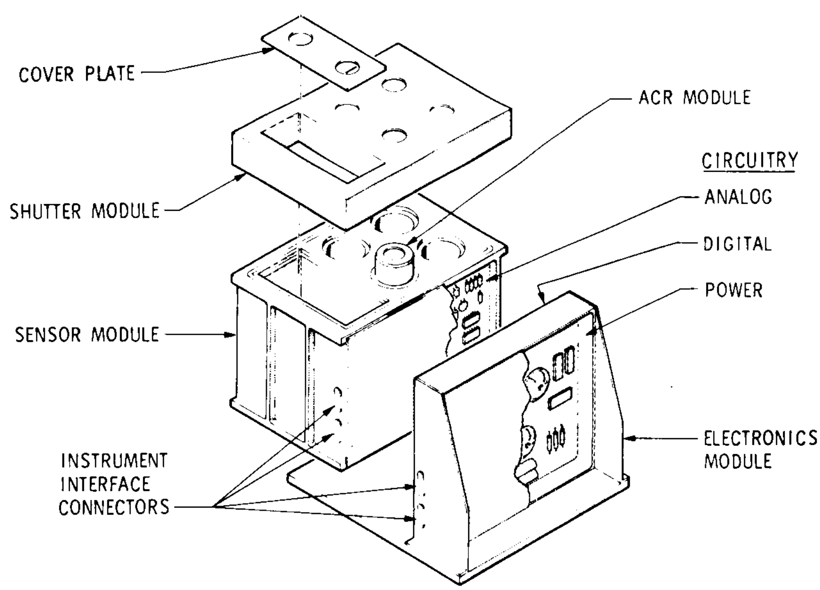

Figure II-2. Exploded view of Jet Propulsion Laboratory's ACR for ATLAS 1.

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MEASUREMENT OF THE SOLAR CONSTANT (SOLCON) (E021)

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The objectives of this investigation are: (1) to measure the absolute value of the solar constant with improved accuracy, and (2) to detect and measure long-term variations that may exist in the absolute value of the solar constant.

The solar constant is the total irradiance of the Sun at a distance of one astronomical unit. This will be measured directly in space by an absolute self-calibrating radiometer with an absolute accuracy estimated to be of the order of ±0.1 percent and a sensitivity better than 0.05 percent.

The values for the solar constant obtained by measurements since 1960 lie between 1353 ± 20 W/m^2 and 1392 ± 14 W/m^2. This dispersion is caused by the inaccuracies and scale problems of the instruments which have been used and the need to correct measured values for atmospheric attenuation. The use of an absolute radiometer removed from the effects of the atmosphere with its calibration tested in situ is the only way in which a truly accurate measurement of the solar constant can be made. Through the use of such space borne instruments, the situation is now improving.

The need for an accurate measurement of the solar constant has been recognized for some time, and improvement of the value has been strongly recommended by several scientific bodies. The absolute value of the solar constant is a critical element in the determination of the Earth's radiation budget as well as for the studies of Earth albedo. In addition, it is one of the main components in the energy balance equation for the Earth and its atmosphere, and is responsible for the dynamic behavior and circulation of the atmosphere and, thus, also the climate. For climatology and atmospheric physics, the importance of an accurate knowledge of the value of the solar constant and its variations over long time periods cannot be overstressed.

The special feature of this radiometer (Fig. II-3) is that it has two channels which enable the detection of and compensation for any degradation of the black surfaces, and the determination in space of the self-consistency of the radiometric system. The radiation measurement will be made by using a heat balance system automatically driven by a feedback system. The precise knowledge of the electrical, optical, mechanical, and thermal characteristics makes this radiometer an absolute instrument which does not need to be calibrated by radiative sources.

Each of the two radiation sensors has an independently controlled shutter. The radiometer is operated by using various combinations of open and closed shutters and a reference electrical power source which has a stable and known output.

At the beginning and end of each measurement sequence, the correct behavior of the radiometer system is ascertained by having the shutter of both channels closed, applying the reference power source to one heater, and using the servosystem to adjust the power applied to the other until heat flux balance is achieved. The roles of the channels are then reversed and the same procedure followed. The measurement of the electrical power applied to each channel for the two cases gives a value for the

precision of the servosystem. Because the power of the reference electrical source is already known, this is a simultaneous check of the data processing system.

The actual radiation flux measurements are made by pointing the radiometer to the Sun's center and opening the shutter of the channel to which the servosystem power is attached. The servosystem compensates for the extra heat input until heat flux balance is achieved again. The shutter is then closed, and the servosystem should adjust the power back to its previous value. The difference in the power applied with the shutter opened and closed is a function of the incident radiation flux. The absolute total irradiance can be calculated from the known characteristics of the instruments. This sequence of opening and closing the shutter will be repeated several times, always using the same channel for the measurement.

On the first and last measurement sequences of the mission, the roles of the channels will be reversed for just one step, and the shutter of the channel that is normally closed will be opened. In this way the radiation measurements of the two channels can be compared to detect and compensate for any aging of the black paint of the absorption surface that is repeatedly exposed to the Sun.

The strategy for these long-term observations using the proposed absolute radiometer is as follows: (1) direct and absolute measurement of the solar constant on the first Spacelab mission which flew in 1983; (2) repetition of the measurements using the same radiometer on subsequent flights; and (3) ground based comparison between flights of the radiometer with spare models and other absolute radiometers, ascertaining the link with the new International Radiometric Reference.

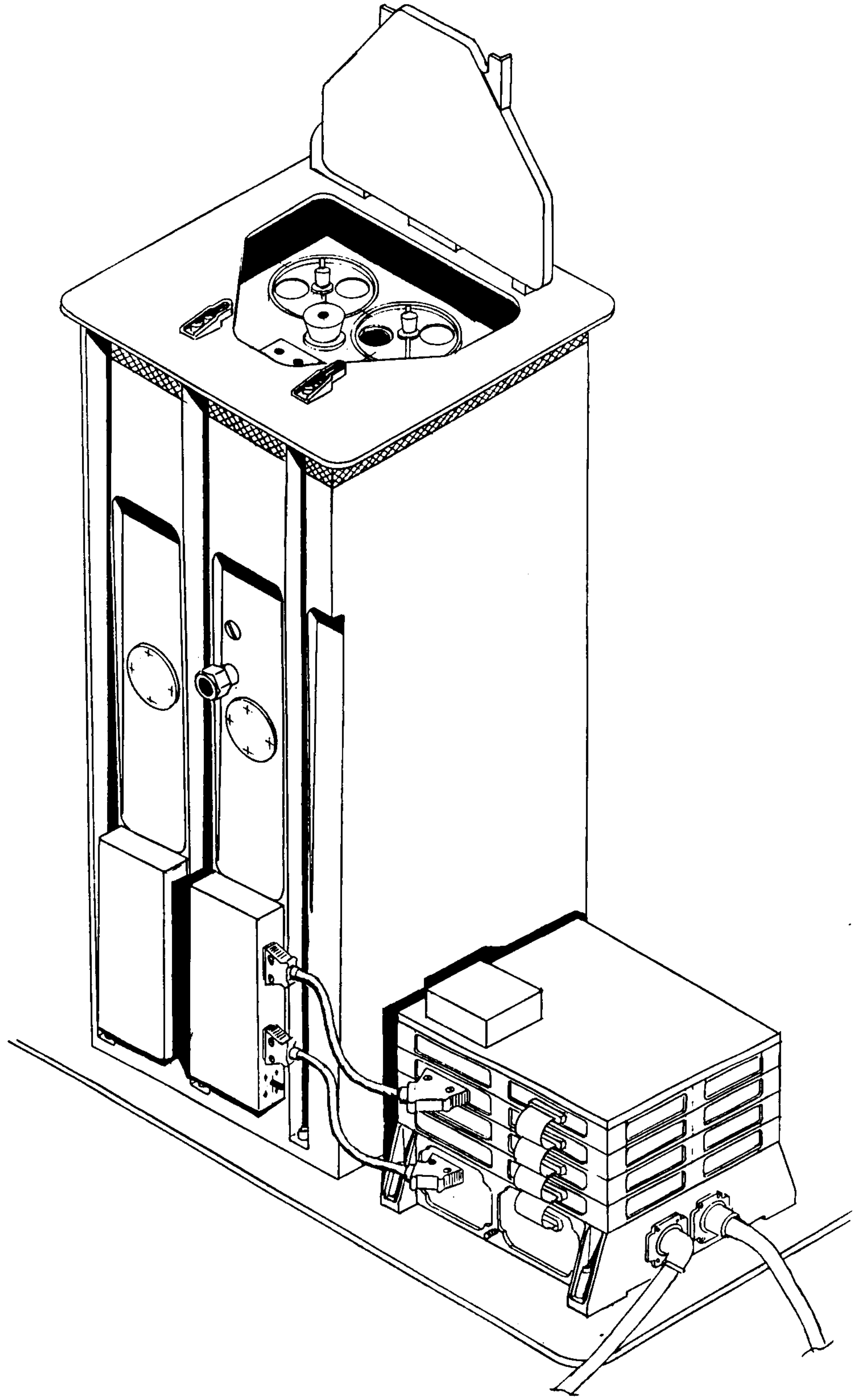

Figure II-3. SOLCON radiometer.

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SOLAR SPECTRUM (SOLSPEC) MEASUREMENT FROM 180 TO 3000 NANOMETERS (E016)

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and

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The purpose of ~~the investigation~~ is the measurement of the absolute solar irradiances in the wavelength range from 180 to 3000 nm and the variabilities of the solar irradiances in this wavelength range. Measurements of the irradiances and variabilities thereto are used in: (1) solar-terrestrial/planetary relationships, in particular aeronomy of the stratosphere and mesosphere; (2) climatology; and (3) solar physics.

The solar variability has several time scales extending from the short-term variations to the 27-day rotation and continuing up to the 11-year cycle. The present investigation is part of a study of long-term variations which needs several flights separated by 12 and 18 months. Post-flight calibration to insure the accuracy of the measurements is essential for this investigation. The present instrument was flown for the first time onboard Spacelab 1. This instrument, in association with the absolute radiometers measuring the total irradiance, will determine which domain of the solar spectrum is responsible for any observed variations and which region of the atmosphere may respond to such variations. This instrument could also participate in the calibration of Sun spectrometers which may be flown on other missions.

Since the solar irradiance is the primary energy input to the Earth's atmosphere and climate system, a knowledge of its absolute magnitude and variability is fundamentally important. Calculations using simple models of the Earth radiation budget have shown the sensitivity of the global average surface temperature to the absolute value of the solar irradiance, namely the solar constant and of its variations. If the integrated solar irradiance is needed for determining the net radiation budget at the top of the atmosphere, the spectral distribution of solar irradiance is required in order to know the altitude within the atmosphere at which the solar energy is deposited. Indeed, the absorption and consequently the energy source at different altitude levels depends upon the magnitude of the available solar energy in wavelength intervals corresponding to absorption spectra of atmospheric species. Therefore, spectral intervals must be selected to study the photodissociation processes in the atmosphere and the related aeronomic chemistry. For instance, the ozone distribution, including the HO_x, NO_x, and ClO_x chemistry, is very important for the radiation budget, because it controls the incoming ultraviolet solar irradiance by absorption and the outgoing long wavelength radiation by emission. The temperature, dynamics, and chemistry of the atmosphere are thus directly related to the variability of the ultraviolet irradiance. Therefore, the absolute value of spectral irradiance and its variability are required for aeronomic and climatic modeling.

Many attempts in the past have been made to measure the solar constant and to derive its variability as a function of the solar cycle. All measurements from high altitude observatories, aircraft, or balloons are affected by atmospheric extinction. To compensate for the atmospheric extinction, corrections have to be applied which are valid to a certain accuracy. From those measurements it is difficult to derive

a long-term variability, since the variability is less than the measurement accuracies. From space no corrections are needed, but other problems may arise from the space environment. The data from Nimbus 6, Nimbus 7, and the Solar Maximum Mission (SMM) show a decrease in the solar constant of about 0.02 or 0.03 percent per year from minimum to maximum solar activity. The data obtained onboard SMM have revealed short-term variations of the solar constant with decreases of about 0.15 percent during several days. It should be noted that whereas the UV flux follows the solar activity, the solar constant has shown decreases during periods of high solar activity.

The relation between solar constant variability and spectral irradiances variability is a key problem, since it determines which region of the atmosphere is affected and how it will be affected by the solar output variations. Little is known in this area. Some observations from balloons have found variations at 368, 580, and 770 nm correlated with the variation of the solar constant measured at the same time by SMM. This instrument will extend the wavelength range of such investigations.

The instrument consists mainly of two parts: (1) three double spectrometers, and (2) an onboard calibration device.

The wavelength range extends from 180 to 3000 nm. Three double monochromators are necessary. They use concave holographic gratings of 10-cm focal length mounted on the same mechanical shaft which rotates with a precision of 2 arc sec. The accuracy of the spectral positioning is 10^{-2} nm. Filters placed on wheels at the exit slits remove the second-order signal. A ground glass diffuser is used at the entrance slit in order to reduce the effects of small angle, off axis pointing.

The onboard calibration device consists of two deuterium lamps, two tungsten ribbon lamps, and one hollow cathode lamp. The deuterium and tungsten ribbon lamps are used to monitor changes of the instrument response either on the ground or in space. The hollow cathode lamp permits a determination of the instrument wavelength scale and some bandpasses of the spectrometers. The instrument is calibrated against a black body at 3300 K and a set of tungsten ribbon lamps. An overview schematic is shown in Figure II-4.

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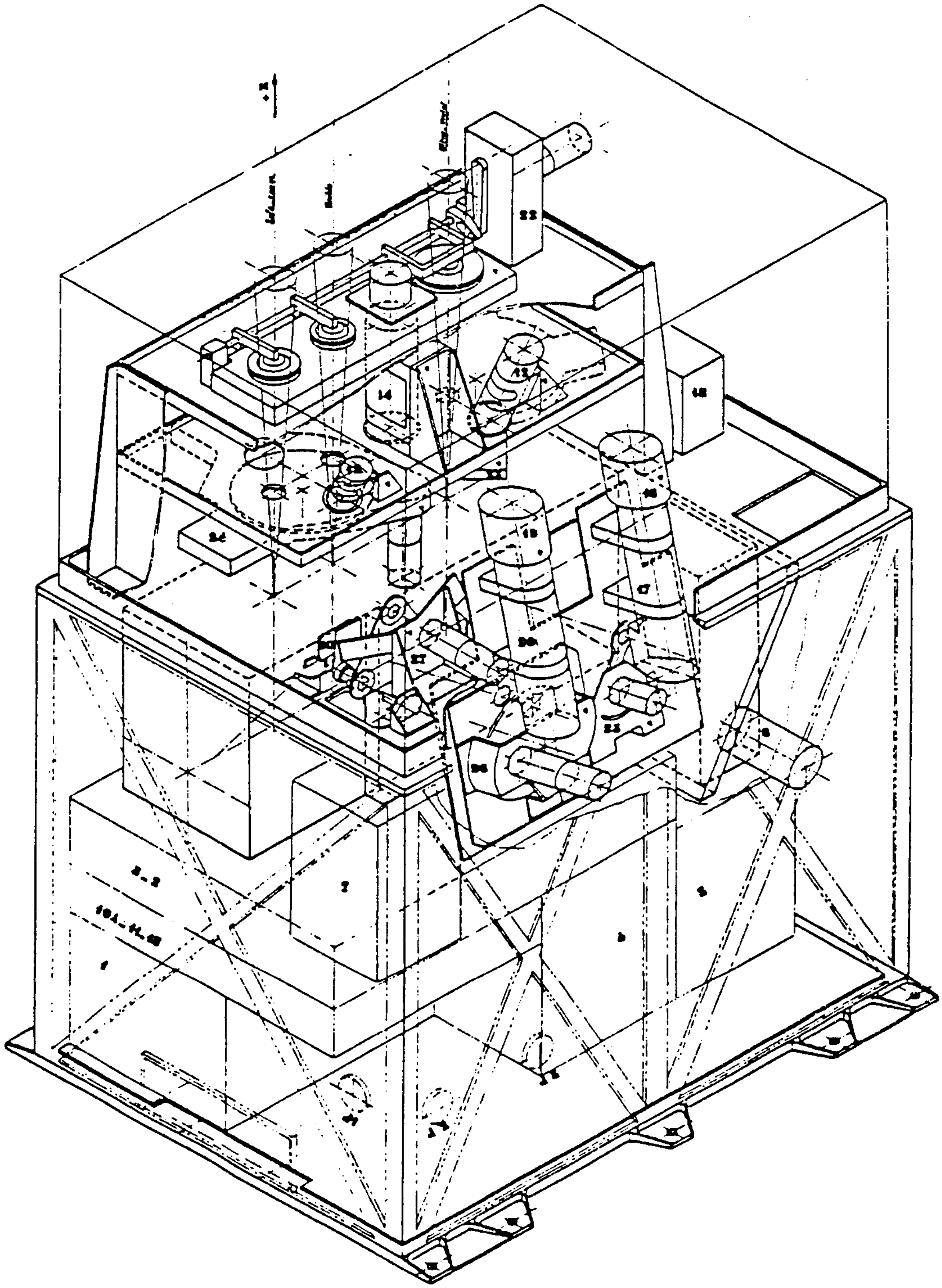

Figure II-4. SOLSPEC instrument overview schematic.

SECTION III

SPACE PLASMA PHYSICS

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18.

ATMOSPHERIC EMISSIONS PHOTOMETRIC IMAGING (AEPI) EXPERIMENT (N003)

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Lockheed Palo Alto Research Laboratory, USA

The basic scientific objective of the AEPI is the investigation of the upper atmosphere-ionosphere and the space shuttle environment. To this end, there are the following experiment areas of the AEPI: (1) the investigation of ionospheric transport processes by observing Mg^+ ions, (2) studies of optical properties of artificially induced electron beams, (3) measurement of electron cross sections for selected atmospheric species, (4) studies of natural airglow; and (5) studies of natural auroras.

Ionospheric transport processes are associated with global patterns of electric fields, neutral winds, and, on a smaller scale, plasma instabilities caused by field and density gradients. Observations show that there is an observable quantity of Mg^+ ions in the E and F regions and the direct imaging of resonance radiation of the Mg^+ ions enables us to study ionospheric transport processes using the natural Mg^+ as the ionospheric tracer. Examples of Mg^+ ion observations from Spacelab 1 are shown on Figure III-1.

Because of the offset of the geographic and geomagnetic poles, the 57 deg inclination orbit planned for ATLAS 1 will provide occasional auroral zone coverage. The nightside auroral zone extends to a magnetic (or invariant) latitude of 65 deg, which is within the ATLAS 1 orbit. Depending on the season during which the flight will be performed, locations in either the northern hemisphere (northern Canada) or the southern hemisphere (south of Australia) will be dark and, therefore, suitable for auroral studies. The high-resolution photometric imager flown on ATLAS 1 will be used to image auroral structures. The topside viewing permits the UV imaging of auroras and the limb viewing capability from orbit also gives a significant advantage over ground-based observations.

Another advantage of this ATLAS mission is the planned coordinated use of several different instruments in a given investigation. In the observation of natural auroras and airglow, the AEPI instrument will provide image data in coordination with the spectral data taken by the imaging spectrometer (experiment N001). Another joint endeavor is the study of induced emission from artificial particle injections using SEPAC (experiment N002). In such a joint investigation with SEPAC on ATLAS 1, an electron beam is directed downward or upward from the Orbiter. The electrons precipitate (either directly or after having mirrored at the opposite hemisphere) and cause artificial auroral emissions under the Orbiter. To satisfy the objectives of such an experiment, the generated optical aurora will be detected with a high signal-to-noise ratio by the AEPI instrument. The morphology of artificially induced auroras caused by mirroring electrons beamed upward (electron echo) and electrons beamed downward (artificial auroras) by the electron gun will be studied.

The objective of the induced equatorial auroral experiment is to measure the electron-impact cross sections of several atmospheric constituents. The experiment involves the ejection of an electron pulse on a magnetic equatorial crossing by the Orbiter, then viewing of the emission returning from the beam path with passive instruments from the Orbiter. The measurement results will include the effective excitation cross section for producing $O^+(^2P)$ and for producing other atomic

metastables from their atmospheric ground states. Pulsed afterglows will also produce a measure of the collisional deactivation rate from some of the highly quenched metastable states. For $O^+(^2P)$, simultaneous sensing of emissions having different emission probabilities (i.e., λ = 7319 Å and λ = 2470 Å) will directly measure the total collisional deactivation at a given altitude.

On ATLAS 1, we will also continue our investigation of the optical emissions generated by the shuttle: the shuttle ram glow.

The experiment consists of the following major subsystems: (1) detector assembly and lens cover, (2) two-axis gimbal (MAST) with MAST electronics and load isolator, (3) pedestal support structure and launch locks, (4) video data encoder (VDE), (5) mount manual control (MMC), and (6) dedicated experiment processor (DEP). Items 1 through 3, depicted in Figure III-2, are located on the pallet and are exposed to the space environment.

The detector assembly, depicted in Figure III-2, consists of two principal parts: a dual-channel low-light-level television (LLLTV) system and a photon counting array (PCA). The system includes appropriate optical filters to provide spectral sensitivity and incorporates drive mechanisms and associated electronics to control filter wheels, to focus the TV lenses, and to change the TV field of view. The lens cover serves not only as a contamination cover and light baffle, but also houses shuttered light sources used to verify the sensitivity of the instrument in flight.

Another optical system was introduced into the AEPI package for the ATLAS 1 flight: a low-light-level unfiltered (spectral continuum) TV camera. This TV camera consists of an Augeniux 50 mm f/.95 lens which is focused at infinity. The image is formed on a single-stage microchannel plate intensified inverter tube. The intensifier is coupled to an uncooled CCD via a fiberoptic taper.

The dedicated experiment processor (DEP) controls detector functions. The detector electronics perform such functions for the LLLTV as filter wheel positioning, camera focusing, prism movement (FOV), intensifier gain control (HV), and camera control. The appropriate function control for the PCA is filter wheel positioning. In addition, temperature is actively controlled (heater power) with internal temperature monitors to ensure that the narrowband optical filters remain centered on line emissions of interest. In the event that a very bright light source appears in the field of view of either the LLLTV or PCA, a sun sensor protectively disables both systems and commands the filter wheels to assume a mutually exclusve cross-filter position.

The AEPI instrument complement also includes a small hand-held image intensifier and its associated filters and manually operated spectrometer. These instruments are stowed in lockers for launch and landing in the Orbiter. The payload crew can use these devices to monitor a wide variety of phenomena ranging from the low-light-level environment of the shuttle to the Aurora Australis underneath the Orbiter. These low-light-level photographs are taken through the Orbiter windows with the equipment mounted in the window by means of appropriate mounting clamps and lens hoods to exclude Orbiter light contamination.

The experiment requires the ability to acquire track and stabilize on a given target, independent of shuttle attitude constraints. Initial pointing to the target area is automatic. Final alignment to the target is manual, based on a display of the TV image and is done by the Payload Specialist. Tracking commands must be generated based on shuttle and target data because there are no sensor-generated error signals.

A simple two-axis pointing system is used. It can perform those stability and control functions that go beyond the capability of the shuttle. This system is a modified star tracker mount (MAST). The MAST provides experiment pointing over an 80 x 160 deg range.

One of the primary functions of the video data encoder (VDE) is annotating the video with essential housekeeping and experiment parameters. These data are generated in the DEP and passed to the command and data distribution electronics in the VDE, where they are decoded and added to the video. For the ATLAS 1 mission, the DEP and VDE units are mounted on the pallet under the orthogrid structure. A special control panel is mounted in the Orbiter aft-flight deck. The Payload Specialist can interact with the DEP via the control panel and vary parameters in operational sequences which are pre-programmed for each functional objective.

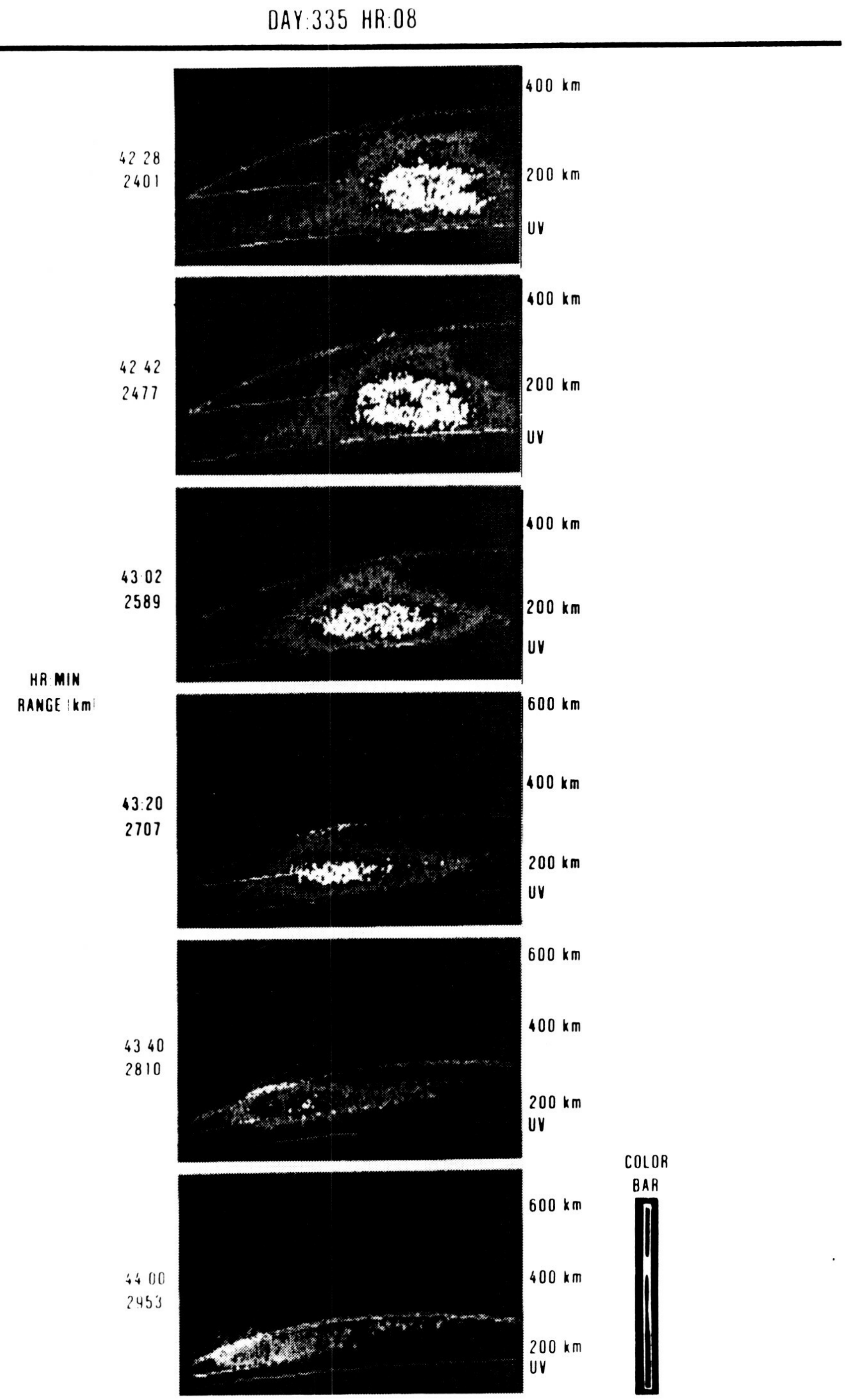

Figure III-1. Examples of Mg^+ data taken with the AEPI instrument on Spacelab 1.

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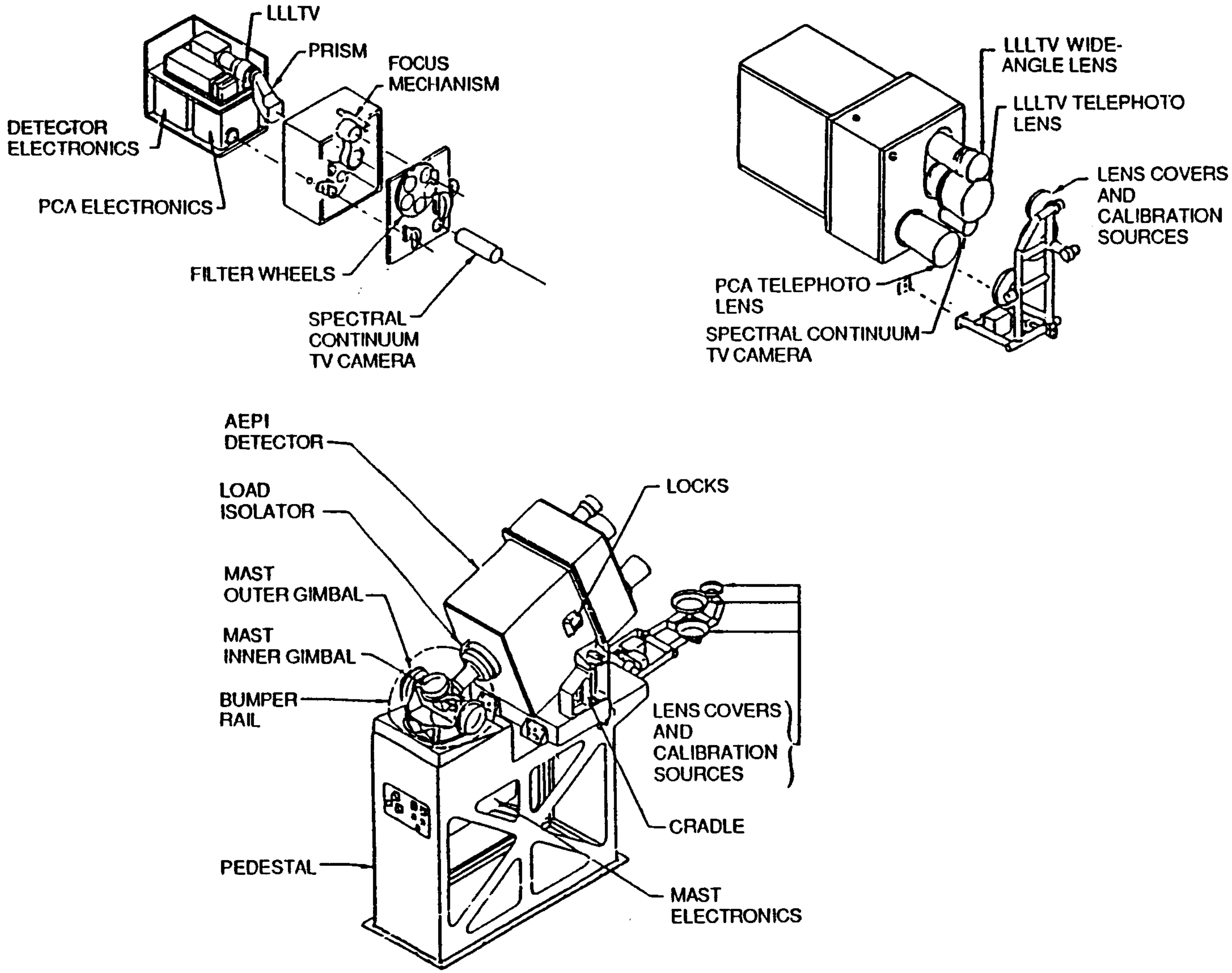
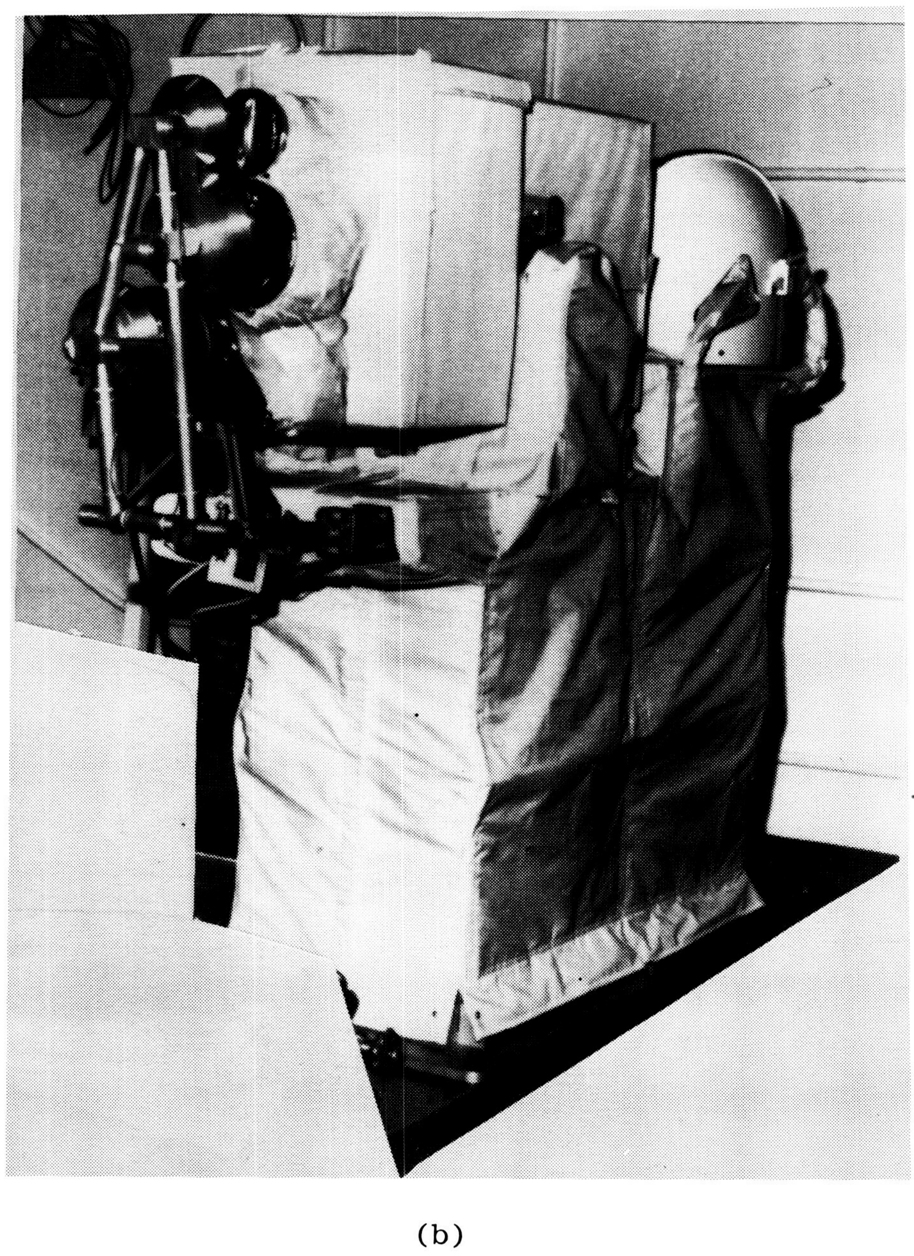


Figure III-2. (a) Elevated isometric illustration of the AEPI pallet-mounted equipment, including pointing mount, detector, pedestal, load isolator, and launch locks.



(b)

Figure III-2. (b) AEPI pallet-mounted equipment shown with thermal blankets prior to integration at Kennedy Space Center.

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SPACE EXPERIMENTS WITH PARTICLE ACCELERATORS (SEPAC) (N002)

Tatsuzo Obayashi
Institute of Space and Astronautical Science, Japan

The purpose of Space Experiments with Particle Accelerators (SEPAC) is to carry out active and interactive experiments on and in the Earth's ionosphere, atmosphere, and magnetosphere. The instruments (Fig. III-3) to be used are an electron beam accelerator (EBA), plasma contactor, and associated instruments the purpose of which is to perform diagnostic, monitoring, and general data taking functions. All are mounted on the pallet. Command and display systems are located in the aft flight deck.

Four major classes of investigations are to be performed by SEPAC. They are: beam plasma physics, beam-atmosphere interactions, the use of modulated electron beams as transmitting antennas, and the use of electron beams for remote sensing of electric and magnetic fields. The first class consists mainly of onboard plasma physics experiments to measure the effects of phenomena in the vicinity of the shuttle. The last three are concerned with remote effects and are supported by other ATLAS 1 investigations as well as by ground-based observations (Figs. III-4 and III-5).

A systematic examination of various plasma coupling processes will be performed with the beam plasma physics investigations. The injection of an electron beam into a plasma often results in interactions that modify the structure of the beam and its velocity distribution while generating a wide variety of plasma wave phenomena. The instabilities responsible for these effects are of interest because they are manifestations of basic physical processes that occur in beam plasma interactions. Waves generated in the beam-plasma interaction will be detected at ground observation facilities to investigate a possible use of an electron beam as a virtual antenna.

The purpose of the beam-atmosphere interaction investigations is to study mechanisms for the formation of auroras and the excitation of airglow. The physical and chemical processes involved in the formation of natural auroras are complex. The dynamic nature of the aurora and associated rapid changes in the input particle distributions have severely limited the ability to understand the aurora through passive experiments alone. An auroral input-output experiment, wherein a stable beam of electrons with a narrow spread in energy and pitch angle will be injected into the atmosphere by SEPAC, should significantly advance the understanding of auroral phenomena. Artificial auroras that are produced by firing the electron beam accelerator upward into the magnetosphere will be used to search for electric fields parallel to the magnetic field in the auroral zone. These fields may reflect the beam causing it to impact the atmosphere below the Orbiter.

The SEPAC instrumentation is divided into three groups: the active elements; the monitor and diagnostic instruments; and the control, display, and data management equipment.

The active elements are the electron beam accelerator, plasma contactor, and neutral gas ejector. The electron beam accelerator is capable of operating at voltages from 500 V to 7.5 kV at a maximum of 1.6 amps.

The plasma contactor produces a xenon plasma which will clamp the electrical potential of the Orbiter to the plasma potential, allowing the full 1.6 amps of electron current to be ejected from the EBA. The third active element is a neutral gas ejector which ejects xenon into the ionosphere.

Monitor and diagnostic instruments to be used are a beam monitor television, a photometer, an energetic particle analyzer, plasma probes, and plasma wave detectors.

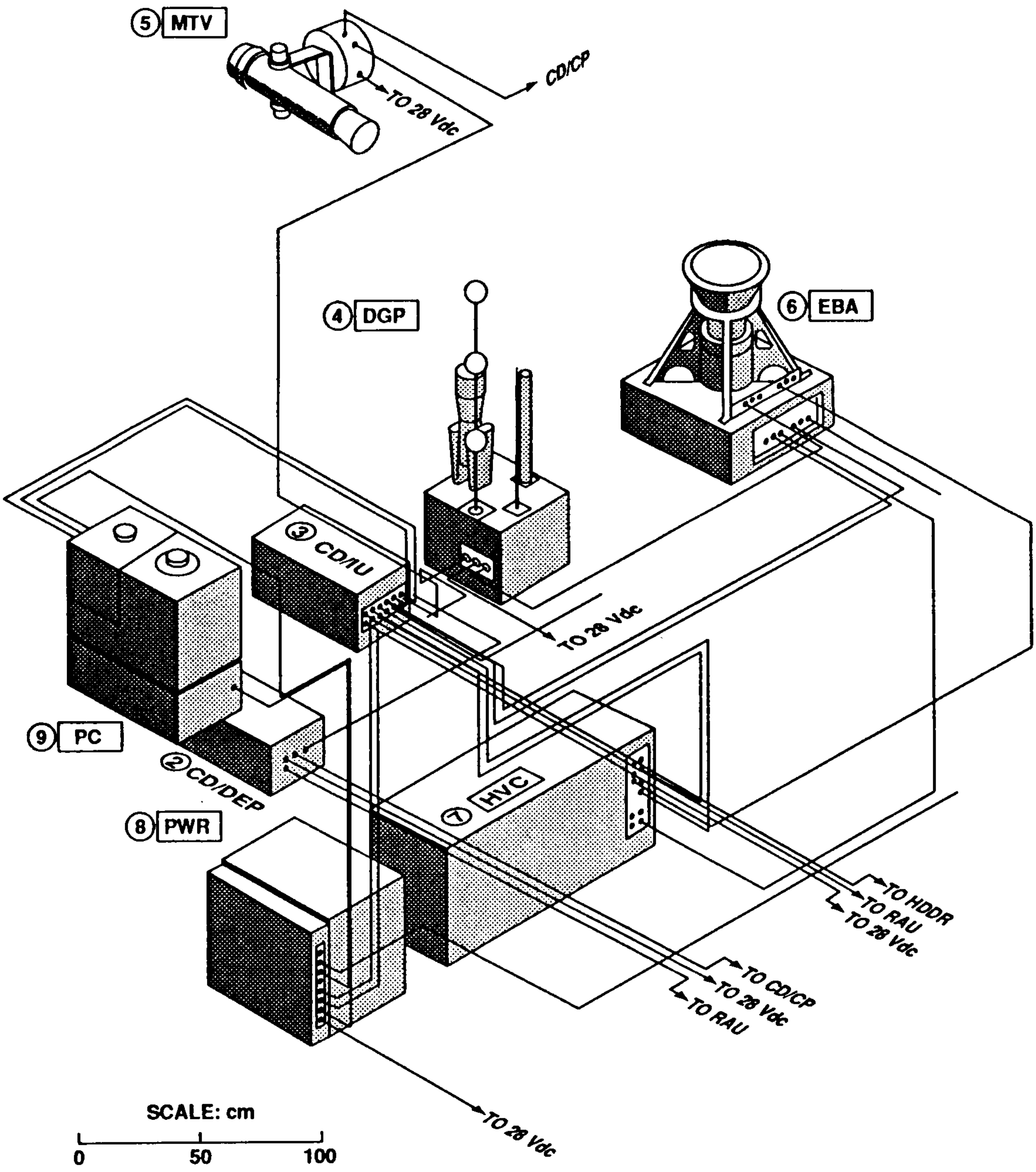

Figure III-3. Layout of SEPAC equipment.

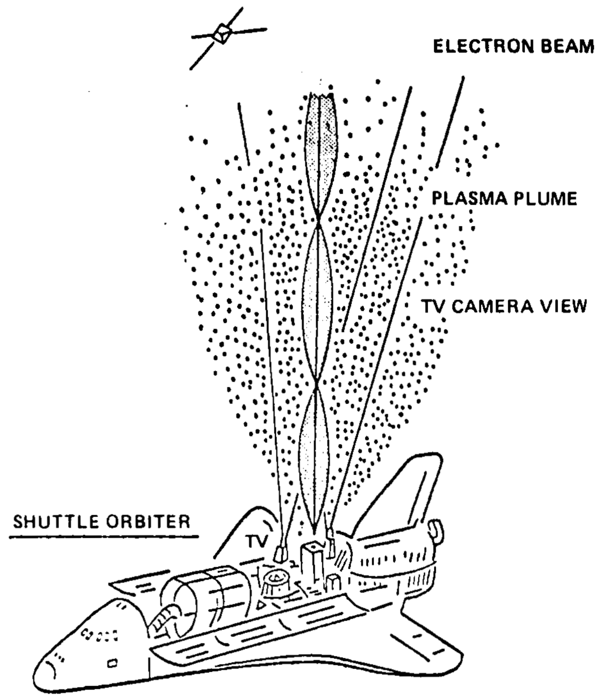

Figure III-4. SEPAC experiments in the vicinity of the Orbiter: beam plasma physics.

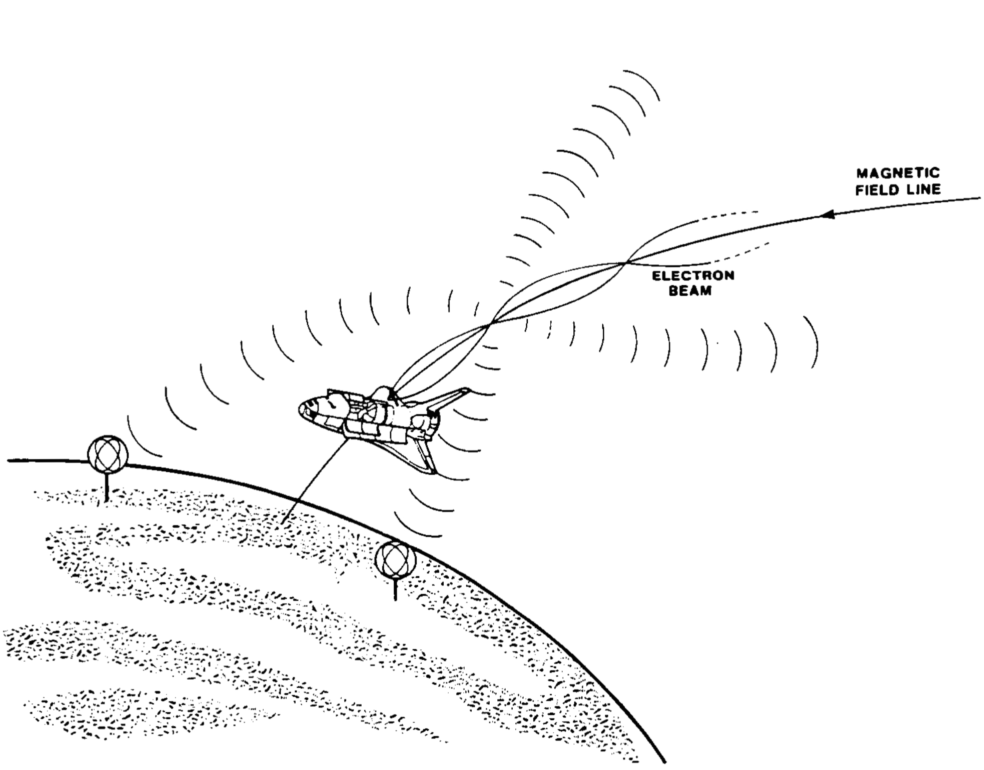

Figure III-5. SEPAC virtual antenna experiments.

SECTION IV

ASTRONOMY

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FAR ULTRAVIOLET SPACE TELESCOPE (FAUST)
(N005)

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The Far Ultraviolet Space Telescope is a compact, wide field-of-view, far ultraviolet instrument designed for observations of extended and point sources of astronomical interest. The instrument was developed under Professor G. Courtes of the Laboratoire d'Astronomie Spatiale and the French Space Agency (CNES); it was originally used in sounding rocket work by both French and American investigators. The instrument was modified for flight on the space shuttle and flew on the Spacelab 1 mission as a joint effort between the Laboratoire d'Astronomie Spatiale and the University of California, Berkeley.

The prime experiment objective is to observe faint astronomical sources in the far ultraviolet with sensitivities far higher than previously available. The experiment will cover the 1300 to 1800 Å band, which is inaccessible to observers on Earth.

The observing program during the mission consists of obtaining deep sky images during spacecraft nighttime. The targets will include hot stars and nebulae in our own galaxy, faint diffuse galactic features similar to the cirrus clouds seen by the Infrared Astronomical Satellite (IRAS), large nearby galaxies, nearby clusters of galaxies, and objects of cosmological interest such as quasars and the diffuse far ultraviolet background.

The instrument is an f/1.12 Wynne camera with an effective collecting area of 150 cm^2 and a field-of-view of 8 deg (Fig. IV-1). The imaging capability is 2 arc min over the entire field-of-view. The telescope used a photographic detector system for the Spacelab 1 and sounding rocket flights. For the ATLAS 1 flight, a new all-electronic, photon counting imaging detector has been developed by the Space Astrophysics Group at the University of California, Berkeley. The new detector will provide very high sensitivity. Because the data may experience intermittent background contamination from geophysical or shuttle related causes, the new detector also provides the ability to select the highest quality data from the continuous data stream. The data will be monitored in real time at the Payload Operations Control Center.

The overall instrument, which includes a sealed container with a mechanical door, is a cylinder 60.0 cm in diameter and 120.3 cm in length. When used in a photometric mode with a bandpass of approximately 500 Å, the limiting magnitude for a 20-min observation is V = 17. Diffuse sources as faint as 27th magnitude per square arc second can be detected.

The instrument will be hard-mounted on the pallet and will be operated automatically by a computer. Should this new automatic mode fail, the instrument can be operated in a manual mode by the payload crew. Secondary data concerning various observation parameters and housekeeping data will be available to the Payload Specialist and to the experimenters at the Payload Operations Control Center.

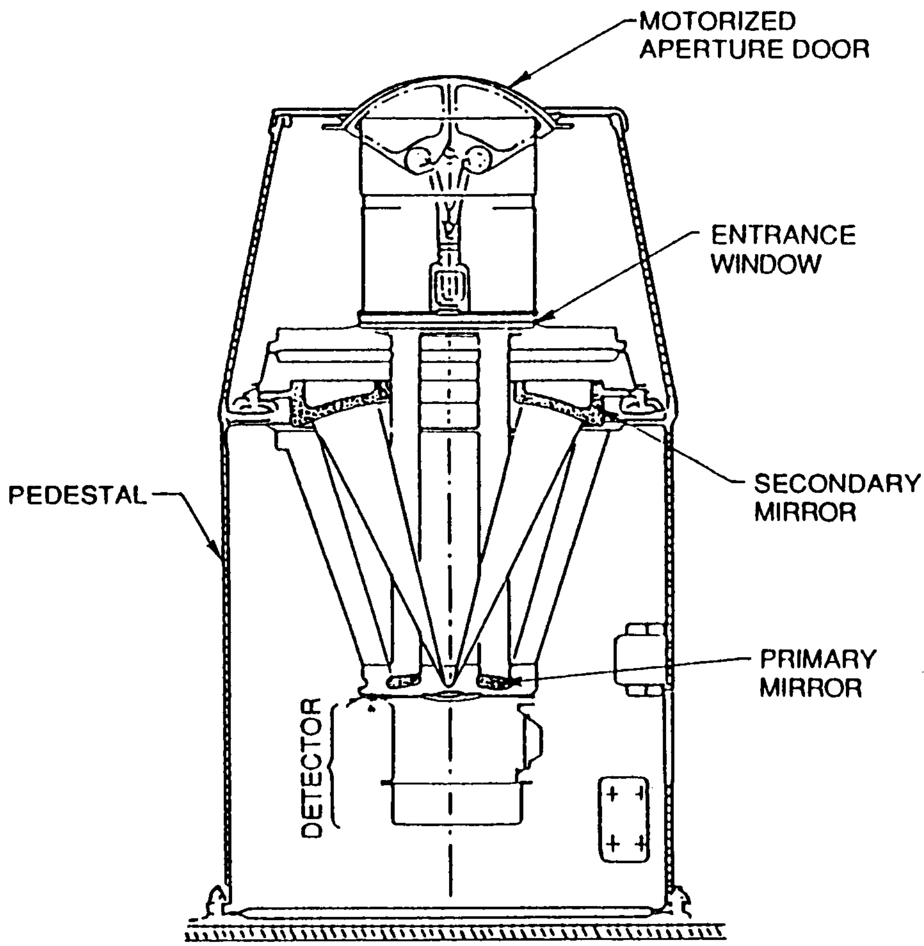

Figure IV-1. Schematic of the FAUST telescope.

OMIT TO END

APPENDIX

LIST OF CO-INVESTIGATORS AND OTHER TEAM MEMBERS

APPENDIX
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1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA TM-4101		

4. TITLE AND SUBTITLE	5. REPORT DATE / 6. PERFORMING ORGANIZATION CODE
Atmospheric Laboratory for Applications and Science Mission 1	October 1988 / ES53
7. AUTHOR(S) Paul D. Craven and Marsha R. Torr, Editors	8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812	10. WORK UNIT NO. M-607 / 11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546	13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum / 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Space Science Laboratory, Science and Engineering Directorate.

16. ABSTRACT

A brief description of each of the experiments selected for flight on the first Atmospheric Laboratory for Applications and Science (ATLAS) mission is given in this report. Each description has been prepared by the investigator responsible for the experiment. Most of the experimental equipment on ATLAS 1 has been flown before on one of the first three Spacelab missions.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
ATLAS, Atmospheric Laboratory for Applications and Science, Spacelab, Shuttle Space Plasma, Atmospheric Physics, Solar Physics, Astronomy	Unclassified — Unlimited Subject Category: 12

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	80	A05

For sale by National Technical Information Service, Springfield, Virginia 22161

NASA-Langley, 1988